SHELL PUBLIC HEALTH AND AGRICULTURAL NEWS NUMBER 3 OCTOBER 1958

Magnified x 125 approx.

Not marked on the map

In the land of the granite *kopjes*, where the sand loam lies over the red and yellow clay, tobacco grows bright and green and beautiful to the planter's eye. *Hicks*, *Delcrest*, *Yellow Mammoth*, *Bonanza*, *Gold Dollar* . . . a silky-leafed harvest ripening under the African sun, richly fulfilling the promise of the soil survey map—and the hopes of the farmer.

Yet, until quite recent years, there were fields in the Mashonaland *bundu* where both hopes and tobacco died despite all assurances of perfect soil fertility and texture. The young growing plants sickened and wilted, with roots rotted away, leaves puny and prematurely yellow. ' This ground is *royiwa*,' observed the boys sombrely. ' Here tobacco will never grow.' And the area was abandoned to wilderness and weed.

To-day, many of those fields are bearing rich and rewarding crops. For the unseen—and, for many years, unsuspected—microscopic soil pest which destroyed the crops *but which no map could mark*, has now not only been identified, but brought under economic and effective control. Root-knot nematodes had been known in Rhodesia for many years as a serious pest of tobacco and strict measures of control were continually exercised in order to ensure the production of clean, healthy seedlings from the seedbeds—the basis of a sound crop. Then in 1951-52 the presence of a non-gall-forming species of these voracious parasites was also established. However, both root-knot and root-rot nematodes were brought under control, and in each case Shell D-D Soil Fumigant proved to be the tobacco saviour. Infested lands treated with D-D average an extra 300 lbs. of leaf per acre—a net increase of nearly 50% in the yield and in the value of the crop, even after the cost of treatment is accounted for. *Which puts D-D, in terms of tobacco, well and truly on the map.*

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Our cover picture is of a completed groundnut pyramid at the railhead at Kano, Nigeria. Photo: *The Times.*

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Banana Spraying with Mineral Oils

a new control for leaf spot

by **A. J. A. Pearson,** *Woodstock Agricultural Research Centre.*

In all the major banana producing areas of the world, leaf spot, or Sigatoka, caused by the fungus *Mycosphaerella musicola* (Leach) (*Cercospora musae* Zimm.) is one of the more important diseases which attack this crop. Only in exceptional circumstances are the plants actually killed by the pathogen, but under normal conditions the damage caused to leaf tissue, with the subsequent reduction in photosynthetic area, is so great that unless control measures are taken, the loss of weight of fruit becomes a major economic factor.

Like many other fungi which attack leaves, the pathogen can be controlled by applications of sprays containing copper or the newer synthetic fungicides. However, since a banana plant produces a new leaf every 10-14 days, and this new tissue is subject to immediate infection, protective sprays need to be applied at very frequent intervals, and it is common practice to apply 12-17 sprays during the year. Materials and labour expended on leaf spot control are, therefore, one of the chief items of expenditure.

Recently, a new and revolutionary method of leaf spot control was found by Guyot and Cuillé (1955) working in Guadaloupe. These workers had been experimenting with fungicides suspended in mineral oil for application by mist blowing machines at very low volume. It transpired that mineral oil alone, without the conventional fungicides, gave a satisfactory control of the disease, and as a result, the technique of ultra low volume oil spraying is fast becoming an established practice. The principal advantages of the method are that water is not required (which is of particular value in certain areas where supplies and terrain are difficult); the operation is much more speedy; and aerial spraying methods can be employed. Thus the costs of application are substantially reduced.

This low volume oil spraying technique was found, however, to have one important drawback—the phytotoxicity of many mineral oils. Even at the very low dosage rates used (2-2½ gal.[1] per acre) they were capable of producing quite severe symptoms of leaf scorch, and damage to the fruit was liable to occur if the spray was not correctly applied.

It was with this phytotoxicity problem in mind that the author recently spent six months in Jamaica carrying out oil spraying trials. The remainder of this article is concerned with the results of this work.

The main groups of compounds present in oils of the light lubricating type are paraffins, naphthenes, olefins and aromatics. The proportions of these vary depending upon the source of the crude oil and the degree and method of refinement. Mineral oils have long been in use as agricultural chemicals for insect and weed control, and thus there is a considerable amount of information concerning their biological performance (Ebeling, 1950). In general, it can be said that aromatic compounds, particularly those of the polycyclic type, are highly phytotoxic. Paraffins and naphthenes are the least damaging to plant tissue. The factor of viscosity has also been studied, and, again generally speaking, since higher viscosity products do not penetrate plant tissue so rapidly as low viscosity ones, the former are normally less phytotoxic.

Although there are a number of other factors in oils of the type under consideration which may affect field performance, three of them were felt to be of particular importance. These were (a) unsulphonatable mineral residues[2], (b) viscosity, and (c) the relative proportion of paraffins or naphthenes in the oil. The experiments reviewed below were therefore designed to evaluate the effects of these factors, and the oil blends used were chosen accordingly, as shown in Table I

Table I
Oils Used in the Trials

UR	*Viscosity, secs. S.U. at 100°F*		
	65-80	*120*	*180*
70-80	P and N	P and N	N
85	P and N	P and N	N
90	P and N	P and N	N
99	N	N	N

P=paraffinic oil. N=naphthenic oil.

These distillates were applied to the banana foliage by one of the methods outlined below.

Methods of Application

Leaf tests.—For assessment of leaf spot control, the right

[1] Throughout this article application rates are given in Imperial gallons.

[2] Unsulphonatable mineral residue (normally abbreviated to UMR or UR) is the percentage of a petroleum oil fraction which will not react with sulphuric acid. UR is indicated by a number in a scale rising from zero to 100, the higher numbers being assigned to the more highly refined products.

The right-hand sides of these two banana leaves have been sprayed with 1 ml. oil; the left-hand sides have not been treated. Leaf spot has completely destroyed the tissue on the unsprayed sides, whereas the oil has given complete control of the disease. (Treatment H—naphthenic oil; R—paraffinic oil.)

A stem of fruit sprayed with a naphthenic oil of UR 70. This has severely burned the fingers, particularly at the tips. (Compare with the picture on the right.)

A stem of fruit sprayed with a naphthenic oil of UR 99. There is almost no damage to the banana fingers. (Compare with the picture on the left.)

or left upper surface of a single leaf was sprayed with a small volume of test oil. The portion of the leaf on the other side of the midrib was left unsprayed. The progress of the disease, which normally begins with the exhibition of symptoms at the leaf tip, was then studied on each leaf half.

For assessment of phytotoxicity, leaves were torn into sections and one oil was applied to each section either by spraying or by carefully rubbing the leaf surface with oil-soaked cotton wool.

Mist blowing tests.—Oils were applied to plots of bananas in the conventional manner using a shoulder-mounted motorised knapsack sprayer, of the type in which the air for the atomisation is first used for cooling the cylinder. This was previously calibrated so that any given dosage, regardless of the oil viscosity, could be applied. The machine was carried between the banana rows with the nozzle held at about 45 deg. to the horizontal.

In one test, to ascertain the phytotoxicity of oils to the fruit, young stems were sprayed by directing a one-second burst of oil on to them from a distance of 5 ft.

Assessments of disease control and phytotoxicity were made by a visual estimation of the percentage leaf infection (based on the method described by Leach, 1946) or degree of phytotoxicity. The damage observed varied from chlorosis to complete destruction of the tissue, a common intermediate stage being brown to black streaks of necrotic tissue.

Control of Leaf Spot

Both the small scale leaf tests and the mist blowing trials demonstrated the effectiveness of oil for the control of leaf spot. All the oils applied gave a significant control of the disease, and, taking the experiments as a whole, there were no significant differences between the results obtained from any one blend, although very low rates were not applied.

In an area where leaf spot was potentially severe, a rate of 1.0 gal. per acre of oil was sufficient to keep the disease in check, but after two months of 14-day applications the infection index on the treated plots was approximately the same as at the beginning of the experiment (about 10 per cent. infection in leaves 2-8). After a further two months of spraying on the same cycle with 1.6 gal per acre, however, the disease was reduced to almost negligible proportions, although on unsprayed plots there was an increase to about 15 per cent. infection with many lower leaves severely affected.

It was clear from one experiment that, if symptoms of the disease existed on a leaf at the time of spraying, oil would not prevent the extension of these symptoms. In all cases, however, provided that symptoms were not apparent when the oil was applied, although infection was known to have occurred, then the progress of the disease was virtually halted by the oil treatment. The material, therefore, appears to exert at least a partial eradicant action, rather than the purely protective effects of Bordeaux mixture.

The mode of action of oils in controlling leaf spot is still not well understood. As a result of observations made in these trials, however, it is clear that oil does exert an eradicant action, probably within the tissue of the host plants. The evidence is empirical, but it is certain that oils of this type are absorbed into the tissue via stomata and move intercellularly in the plant (Van Overbeek and Blondeau, 1954). It is also known that the leaf spot fungus penetrates through stomata and ramifies between the plant cells. It is quite possible, therefore, that oil absorbed into the leaf causes a small change in the intercellular environment which is sufficient to upset the balance necessary for the successful development of the fungal hyphae.

Phytotoxicity

The trials clearly showed that the only factor of the three which were studied (unsulphonatable mineral residue, viscosity and relative proportion of paraffins and naphthenes) that influenced the degree of phytotoxicity was that of unsulphonatable residue. In the single leaf trials, where large amounts of oil were applied, it was shown that the oils of UR 70 caused severe burning and subsequent complete necrosis of the tissue. Even highly refined oils gave some symptoms of damage. In the mist blowing trials, at rates of application of about 1.0 gal. per acre there were only small differences between the various treatments, but when these rates were increased to over 2.0 gal. per acre then the unrefined oils showed their damaging effects. Naturally, much depends upon the environment in which the plants are growing, and under excellent conditions less refined oils do not give such severe symptoms. It was concluded, however, that oils with a UR of less than 80 should not be used on bananas, and, consistent with the cost of the product, oils of UR exceeding 90 are desirable.

Viscosity is related to boiling point and molecular weight, and it was expected that some differences in phytotoxicity due to this factor would be apparent (Van Overbeek and Blondeau, 1954). In fact, no significant differences were observed, and it is concluded that, within the viscosity range used, the experiments were not sufficiently sensitive, or the effects were masked by other factors.

Cuillé and Guyot (1954) have discussed the importance of droplet size in connection with banana spraying, and have shown that, other factors being equal, this is proportional

to the viscosity of the product used. From a practical point of view, therefore, the choice of viscosity is dependent to a large extent upon the machine which is being employed for application. In this connection, the particular sprayer used would not apply volumes of over 2.0 gal. per acre of oils with a viscosity greater than about 150 secs. S.U. @ 100°F. unless the walking speed of the operator were reduced, and for this reason alone the more mobile oils are recommended for ground application with machines of this type.

Similarly, no differences in phytotoxicity could be observed between paraffinic and naphthenic oils of the same UR value. Generally speaking, the paraffinic oils have been favoured for insect control (Pearce, *et. al.*, 1942), and highly naphthenic blends have not, therefore, been so extensively used. Heringa and Swarbrick (1952) found that naphthenic spindle oils of UR>80 were not phytotoxic to cucumber plants, and the Jamaican trials have shown that there is no particular need to use paraffinic oils for leaf spot control if equally refined naphthenic oils are available.

Two trials carried out specifically on fruit showed that, when the banana fingers received a deposit of oil droplets, small grey marks appeared almost immediately. When highly refined oils were used it was rare for these marks to result in tissue necrosis, but with poorer quality products the spots tended to turn brown, and in severe cases the fruit dried out and split. Provided that the spots did not turn brown they were invisible on ripened fruit. It was clear, however, that even a few oil droplets settling on the 'fingers' resulted in some unsightliness, and that every effort should be made to keep to a minimum the quantity of oil which contacts the stems.

Furthermore, in connection with application and the necessity for careful supervision of this operation, some attention should be paid to the temperature of the oil being applied. For example, over a temperature range of 70°-100°F. the viscosity of an oil of the type used varies by a factor of approximately 2. Since in the conventional knapsack machines, other factors being equal, the volume applied per acre depends on viscosity, care should be taken to calibrate the machine at a temperature corresponding to that most commonly encountered. It is unlikely that, in tropical areas, where bananas are grown, oil temperatures would vary greatly, but the factor is worthy of consideration, and the use of more highly refined products is indicated to allow a larger safety margin. It certainly seems likely that the odd cases of damage which have been reported are usually due to incorrect application rather than to inherently poor quality products.

In nearly all the experiments the treatments were applied in the early morning, and in none was oil spraying carried out after about mid-day. Generally, the weather conditions were typical of Jamaica, with hot sunny mornings and some cloud in the afternoons. Thus the oils were applied in full sunlight and high temperatures (of the order of 80°-90°F.), conditions which were likely to favour phytotoxicity. Most of the experiments were carried out on non-irrigated plantations, where growth was affected by weather conditions. It was felt, therefore, that any oil which proved to be suitable for banana spraying in these trials would be satisfactory in any other geographical location.

From the trials' results obtained it is clear that mineral oils from quite a wide range will give a satisfactory control of leaf spot, but from the phytotoxic point of view it is desirable to use oils with the highest possible UR value, though the use of very highly refined products may not be justified on economic grounds. On the other hand, oils with a UR of less than 80, though relatively inexpensive, are too liable to cause damage to foliage and fruit. Thus the selection of a suitable oil blend must ultimately be based on a compromise between performance and cost, and it may well be influenced by such factors as local growing conditions and commercial considerations.

At present, it is not known with certainty to what extent an oil can be selected purely on specifications, since there are many factors present in a blend which may influence field performance, and only a few of them have been taken into account in these experiments. However, from the work which has been done, it can be said that an oil having a specification which falls within the following limits should prove to be suitable:

Specific gravity @ 60/60°F.	0.85-0.90
Unsulphonatable residue	>80 (preferably >90)
Viscosity, secs. S.U. @ 100°F.	70-120
Crude type	Paraffinic or naphthenic
K.V.I.	>35
Neut. Value, mg KOH/g	<0.05
Distillation range	300-400°C

(The flash point also will be of importance if the oil is to be applied by aircraft.)

From such a specification range, a series of products may be selected for trial, and since leaf tests alone give the quickest and probably the most accurate information on leaf spot control and phytotoxicity, results can quickly be obtained and an early selection made of the most suitable grade for any given set of local conditions and requirements.

Acknowledgements

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Studies on Translocated Herbicides

by **A. S. Crafts,** B.S., Ph.D., *Professor of Botany, University of California, and Botanist, California Agricultural Experiment Station.*

Widely known for his work with carbon[14] labelled herbicides in the U.S.A., Professor Crafts has recently completed 11 months' research, using these materials, at the University of Oxford. Working with Professor G. E. Blackman at the Agricultural Research Council's Unit of Experimental Agronomy, on a Fulbright scholarship, Professor Crafts has been continuing the studies on the uptake and distribution of translocated herbicides which he started in the United States in 1951. In this article he describes some of the highly important research which he has carried out on this subject so far.

Professor Crafts is well known to many as joint author, with W. Robbins and R. N. Raynor, of the standard textbook, Weed Control *(McGraw Hill, 62s. or $8).*

To kill deep-rooted perennial weeds and woody plants by application of a spray to the leaves one must use a chemical that can move through the plant in the vascular system. George Gray, in California, found that when sodium arsenite was sprayed on to wild morning glory (*Convolvulus arvensis*) under proper conditions the roots would die to a depth of several feet. This was in 1919. Several years of research proved that this translocation of arsenic in the plant takes place in the xylem or woody cylinder of the plant and that it results from a reversal of the normal upward flow of the transpiration stream. The method, known as the acid-arsenical spray, was limited in its application to areas of arid climate and even then it was far from perfect. It is not widely used at present.

When the phenoxyacetic acid compounds were introduced it was soon found that we were dealing with a new sort of translocated herbicide, one that moved through the phloem or bark region of the stem. Furthermore, this movement accompanies the normal movement of food materials in the plant. Requirements for such movement are very different from those of the acid-arsenical method: they demand that the plant be healthy and well nourished, and producing food materials; they demand that there be active growth in the roots as well as food synthesis in the leaves; and they demand that the chemical has low toxicity during its initial penetration of leaves and movement into roots. Highly toxic chemicals, either as herbicides or as other constituents of the spray formulation, produce injury that plugs the phloem and prevents thorough distribution in the lower parts of the plant.

Plant physiologists have studied the processes of food transport in plants for more than a hundred years and yet they are unable at the present time to explain the mechanism of this function in satisfactory terms. Whereas the development and distribution and the degree of specialisation of the phloem tissues indicate that they are the channels through which food movement takes place, if one attempts to calculate the pressure required to produce such movement, one arrives at impossibly high values. This is because the tubes or conduits, the sieve tubes, through which the flow occurs, consist of series of cells with many cross walls, the sieve plates. If these contained open pores, as the name sieve tube implies, there would be no difficulty. But careful study with high powered microscopes has shown that the so-called sieve pores of the end walls are full of protoplasm. And recent studies have proved that this protoplasm is living, and possibly semi-permeable. (*Continued on next page*)

When it became possible to produce 2,4-D with radio-active carbon[14] in the molecule a new and valuable tool for studying translocation in plants was available. Now after 10 years of such study many new facts have been added to our fund of knowledge and a number of new labelled compounds have been produced. Use of these new compounds by comparative methods has eliminated much confusion and we have now demonstrated to the satisfaction of most plant physiologists the fact that labelled herbicides applied to leaves may penetrate to the phloem and move with foods in the plant from the leaves where the foods are synthesized to regions of stems, shoots and roots where foods are being utilised.

In our early studies with radio-active 2,4-D (2,4-D*) we treated bean plants by applying droplets of 2,4-D* solution to leaves. After varying time periods the plants were removed from their culture media and quick-frozen between blocks of dry ice (solid CO_2). Then they were rapidly dried between hot dry blotters. These experiments indicated that 2,4-D* migrated rapidly into the vascular tissues where it moved at high speed to roots, shoot tips and often into other mature leaves. However, if the plants were fractionated into leaves, petioles, stems, and roots while in the frozen state, much less thorough distribution was found and careful studies proved that during the thawing and drying process the labelled tracer was moving through the xylem to regions where drying was taking place. Since this was not natural movement it represented an artifact and hence had to be eliminated.

If the plants in the frozen condition were placed in a vacuum chamber and this in turn was kept in the freezing unit of a refrigerator, the freeze-drying eliminated the artifact and gave the same distribution of the tracer as occurred in the plants that were fractionated while frozen. Now we freeze-dry all plants treated with the radio-active tracers and the autographs produced give a true picture of natural movement in the plants. Below are described some of the results obtained by use of the freeze-drying technique.

The Mechanism of Movement

If 2,4-D containing carbon[14] in the carboxyl position (2,4-D*) is applied to the cotyledon of a young bindweed plant (*Convolvulus arvensis*), and after four hours the plant is killed with dry ice and dried, auto-radiographing will show that the chemical has penetrated the leaf tissues and moved through the vascular channels along the hypocotyl and well down into the roots.

In some plants such 2,4-D* movement was only downward into roots, in others it moved both downward into roots and upward into growing shoot tips. In doing so it by-passed the intervening old leaves. In contrast, if 2,4-D* is applied to a young growing leaf of bindweed that is still importing foods no outward movement takes place.

If 2,4-D* or labelled amino triazole (ATA*) is applied to a chlorotic leaf of variegated *Tradescantia*, no outward movement occurs. If these tracers are applied to green leaves they move out and into regions where foods are being rapidly utilised. These various experiments indicate that labelled herbicides, applied to leaves of plants, penetrate to the vascular tissues and move with food materials from regions of food synthesis to regions of food utilisation; that is from source to sink.

So much for the source. What about the activity of the sink? If a *Zebrina* plant, that has grown for four weeks in tap water and has mature roots that have ceased to elongate, is treated on an upper leaf, no movement outward may occur. If a plant only two weeks out of culture solution, having roots that are still active, is given a like treatment, some movement of the tracer into the roots takes place. If a plant maintained in a continuous growing condition in a culture solution is treated, strong movement into the roots takes place. And if the treatment is repeated an even greater amount of tracer reaches the roots. Evidently the activity of the sink as well as that of the source is important.

If two active sinks are induced in a *Zebrina* plant by pruning away most of the upper leaves leaving only an active growing shoot tip and an active root system, 2,4-D* applied on a median leaf will move both upward to the tip and downward to the roots. And if all but two active leaves are removed and the growing tip is also removed, application to the two active leaves results in downward movement into active roots and shoots at the base of the plant. In other words, movement is reversible if the source-sink relation is reversed.

Comparative Mobility of Herbicides

Now for a consideration of comparative studies. If mature *Zebrina* plants having roots with little growth are treated on median leaves with radio-active 2,4-D (2,4-D*) amino triazole (ATA*) and maleic hydrazide (MH*) it will be found that the 2,4-D* is retained close to the region of application; ATA* will move from treated leaves to roots and upward to growing shoot tips, by-passing mature leaves along the way; MH* will move to roots and to shoot tips

but all intervening leaves will also contain the tracer. We interpret these results as indicating that 2,4-D is retained by living cells and does not move freely through tissues, and that ATA moves more freely but is limited to the phloem, whereas MH may leak from the phloem into the xylem and so move in the transpiration stream. Thus MH may circulate in the plant as does phosphorus and so attain a true systemic distribution.

Studies with barley plants and rape plants show a similar reponse on the part of these species. In addition, radio-active urea and monuron applied to these species prove that urea* produces an autograph resembling that of ATA* whereas monuron* fails to leave the treated leaf but moves only acropetally and concentrates around the periphery. Urea* is probably split to CO_2* and ammonia during penetration; the CO_2* is rapidly synthesised to sugar* and moved along with other foods. Monuron* apparently is unable to enter living cells; it seems to move along the non-living cell-wall phase in the stream of moving water.

When one treats one of the three older expanded leaves of barley seedlings having four expanded leaves with 2,4-D*, the tracer is carried into roots; treatment of the fourth (youngest) expanded leaf does not result in movement into the roots; the chemical remains mainly in the treated leaf. If one repeats this experiment with older plants movement to roots occurs only from the lowest healthy leaf.

Comparative tests with MH* prove that this more mobile material will move to roots in greater amounts than does 2,4-D*; however, less is moved to roots as leaves higher on the axis are treated. And a comparative experiment proved mobility to decrease through the following series: MH*, Dalapon*, ATA*, Urea*, IAA*, 2,4-D*, monuron*; there was no phloem movement in the case of the monuron*.

When these compounds are applied on the top surface of blocks of potato tuber tissue they follow the same order with respect to movement through this relatively undifferentiated tissue with the exception that urea* is apparently split to CO_2* and ammonia and the CO_2* is lost to the atmosphere; after 16 days the label was entirely lost from the tissue. Monuron meanwhile moved in the non-living cell-walls and concentrated in the peripheral layers where evaporation was taking place.

These studies indicate the wide range in mobility shown by various labelled compounds. The potato block experiment proves that the initial migration through relatively unspecialised parenchyma may largely determine the extent of distribution of a given compound. And the tests in which different leaves received the application show the importance of coverage as related to distribution.

By the use of radio-active tracers the leakage of applied chemicals from the phloem of roots through the cortex to the culture medium or through the ground parenchyma to the xylem has been found to be of common occurrence. This is an important aspect of the physiology of plants. It allows for detoxification by loss to the soil and it makes for complete systemic distribution when loss is to the xylem. This latter type of movement should characterise a good systemic pesticide which suggests the auto-radiographic technique as a testing tool for such compounds.

The variation that has been found in the mobility among the few compounds tested should encourage further testing in the search for highly mobile toxicants. Instead of trying to make a perfect translocated herbicide of the phenoxyacetic acid type of material by formulation or improved application methods it seems more logical to find compounds having the mobility of maleic hydrazide and the toxicity of 2,4-D. Discovery of such compounds may be entirely possible.

Finally, while the studies described do not offer evidence on the mechanism of flow of the assimilate stream through the protoplasmic connections of sieve plates, they do strengthen the evidence for a mass-flow type of mechanism wherein the assimilates and water move together in solution rather than migrate independently as by diffusion. Scientists have known for many years that the plant is able to take advantage of a metastable state of water to move the transpiration stream to the tops of tall trees. Recent work on superfluidity indicates that molecules in a highly ordered state as in liquid helium may move in a way that is unaccountable on the classical concepts of physics.

Possibly the highly specialised cytoplasm of the phloem may exert an ordering influence on the molecules of the assimilate stream in such a manner as to greatly reduce the frictional resistance to flow. However, this is in the realm of speculation and only continued research can provide an answer. Meanwhile the auto-radiographic technique, by giving information concerning the physiology of whole plants, may lead to many improvements in pest control. Already answers to many urgent questions have been found that were completely unanswered ten years ago.

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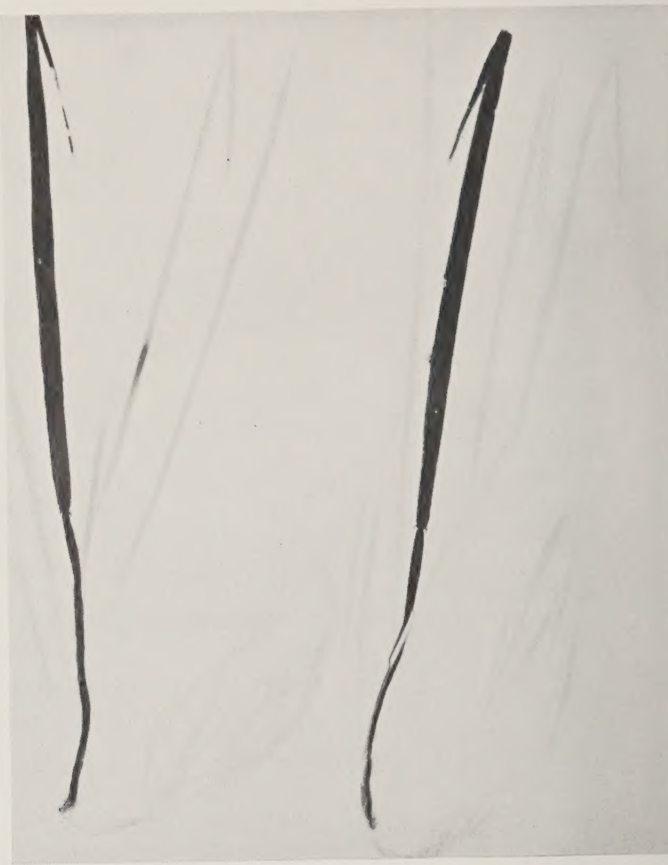
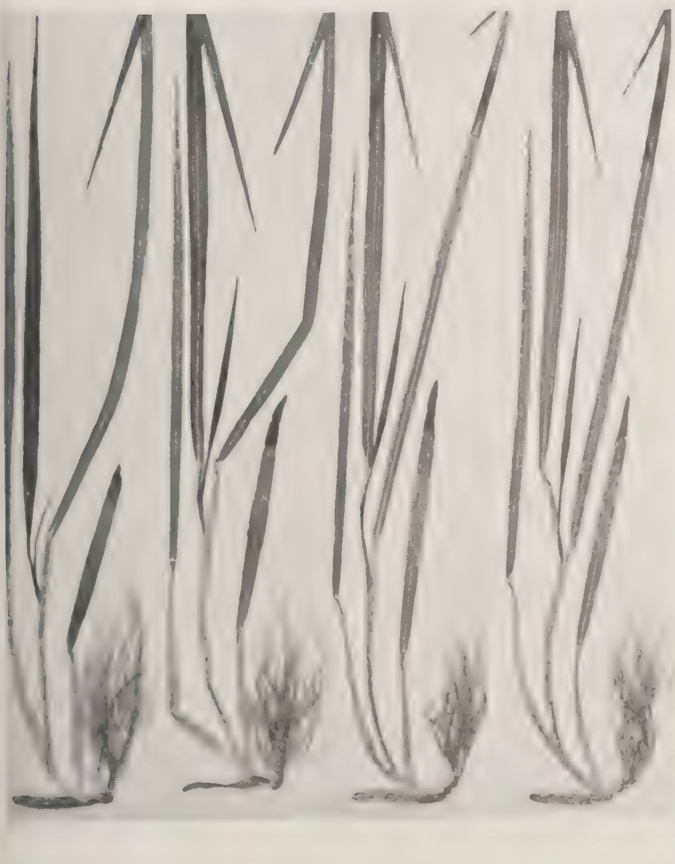


Movement of 2,4-D in barley plants under different conditions.* Left: *two plants treated on leaf No. 1 when three leaves were expanded and allowed to grow for 15 days before they were killed and freeze-dried.* Centre: *two similar plants treated on leaf No. 4, 24 hours before killing and freeze-drying.* Right: *two similar plants treated by adding 2,4-D* to the culture solution at the time the centre plants were treated, and allowed to grow 10 more days.* **Dosage:** left *and* centre *plants, 0.5 micro-curies per plant, applied in 10 micro-litres to single leaves;* right: *1.25 micro-curies per plant in 250 ml. of culture solution.*

2,4-D*

ATA*

MH*



Comparative movement of 2,4-D, ATA* and MH* in barley plants. In each case treatment was to leaf No. 1 on two plants (left on each exposure), and to leaf No. 4 on two plants (right on each exposure). The dose was 0.05 micro-curies with a specific activity of 0.5 milli-curies per milli-mol. Treatment time was 27 hours. The exposure of the plants on the films was four weeks.*

Determining Resistance in Anopheline Mosquitoes

a study in practical genetics

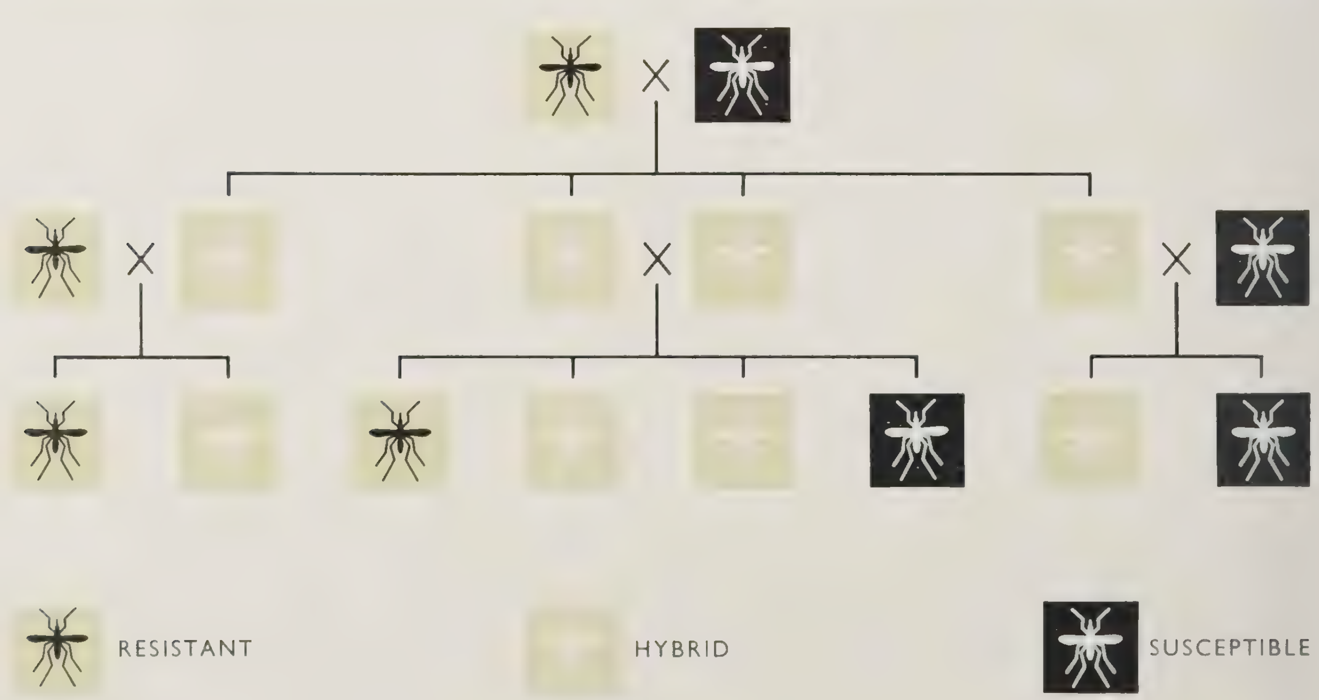
by **G. Davidson,** *Entomologist, Ross Institute of Tropical Hygiene, London School of Hygiene and Tropical Medicine.*

With the exception of Central Africa, in most countries of the world where malaria is an important disease, large scale —often nation-wide—attacks are being made on the anopheline mosquitoes with chlorinated hydrocarbon insecticides. Unfortunately, cases of resistance to these insecticides are becoming increasingly common, and are naturally causing much concern.

The first suspicion of resistance arose in *A. sacharovi* to DDT in Greece in 1951. At the present time six different species of anopheline have shown resistance in eleven different countries. No less than seven of these cases involving four of the species were recorded in 1957. Two of the six species, *A. gambiae* (Africa) and *A. quadrimaculatus* (USA), have so far only shown resistance to the dieldrin-BHC group of chlorinated hydrocarbons. Resistant *A. gambiae* have appeared in four separate areas of tropical West Africa in relatively small-scale control schemes. Considering the small numbers of such schemes in this part of the world, and the doubt that has already been cast on the efficiency of DDT against this species, malaria control in Equatorial Africa has a bleak future if only the present chlorinated hydrocarbon insecticides are available.

A. sundaicus in Java and Burma and *A. stephensi* in three different middle eastern countries have so far only shown resistance to DDT, and a change to dieldrin where this has been made has led to favourable control. *A. subpictus sub-*

Fig. I. INHERITANCE OF DIELDRIN — BHC RESISTANCE IN *ANOPHELES GAMBIAE*



pictus is resistant to the dieldrin-BHC group in Java, and to DDT in India; though it remains to be seen if this species is one and the same in the two countries. This species is not a vector in India, and it is only one of secondary importance in Java. *A. sacharovi* is so far the only species in which resistance to both DDT and the dieldrin-BHC group has been shown in one and the same population.

Resistance, by definition, is the ability to withstand a dosage of insecticide which normally kills the species. In practice, resistance involves the finding of mosquitoes resting completely unaffected on freshly applied deposits of insecticide, and complete failure of the control of the disease which they carry.

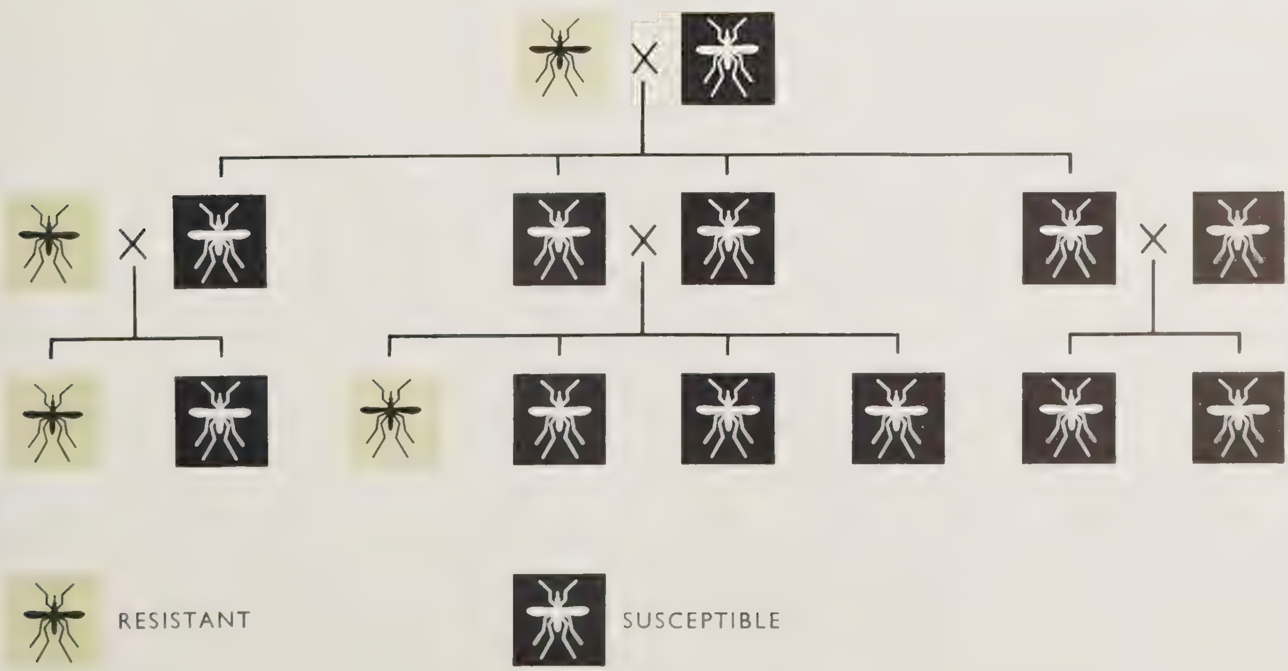
Resistance is an inherent characteristic appearing by chance mutation in a few individuals of a population; it is not an acquired characteristic. It cannot be likened to an increased tolerance to drugs or poisons shown by many animals, including man, when frequent sublethal dosages are taken, though the effect of selection by such sublethal concentrations of insecticides in successive generations of a homogeneous mosquito population, may lead to a slight increase in tolerance, usually not greater than tenfold. The term 'vigour tolerance' has been applied to this phenomenon. Just how important this phenomenon is by itself in the field is not yet known, but it is conceivable that where an insecticide is only just capable of intercepting malaria transmission by a certain vector, this slight increase in tolerance may be sufficient to reduce the mortality in the vector population to below that necessary to intercept transmission. 'Vigour tolerance' is non-specific and as well as applying to all chlorinated hydrocarbons, may extend to other insecticides (e.g. organo-phosphates and pyrethrins).

True specific resistance, on the other hand, is of a much higher degree. DDT-resistance in *A. sundaicus* is of the order of 40 times, and dieldrin-resistance in *A. gambiae* some 800 times. Such resistance, present originally in only a few individuals of the mosquito population, has been selected out by the application of the insecticides. Only the resistant individuals have survived, and their offspring resemble their parents. In other words, by the use of insecticides a resistant population has replaced the original mixed one comprising mainly susceptible mosquitoes, but containing a few resistant ones.

Over the past two years detailed studies have been made, in the insectaries of the Ross Institute, London, on colonies of dieldrin-resistant *A. gambiae* and DDT-resistant *A. sundaicus* and on colonies of susceptible strains of the same species. In the first place, the pattern or spectrum of resistance has been established. *A. gambiae* has been shown to be cross-resistant to chlorinated hydrocarbons of the type which includes chlordane, aldrin, isodrin and endrin and to γ-BHC, though the degree of resistance to the latter compound is only of the order of thirty or forty times. It is, however, as susceptible to DDT as susceptible strains of the same species, and attempts to raise the tolerance by artificial selection in the laboratory with DDT only produced a slight increase, which was lost when selection ceased. It was also shown to be still susceptible to pyrethrins and the organo-phosphate, malathion.

A. sundaicus, which is resistant to DDT, was shown to

Fig. 2. INHERITANCE OF DDT RESISTANCE *ANOPHELES SUNDAICUS*



be cross-resistant to the DDT-analogues, methoxychlor, dichloro-diphenyl-dichloroethane and diethyl-diphenyl-dichloroethane, but still susceptible to dieldrin and γ-BHC.

By crossing resistant and susceptible strains of these two species, the mode of inheritance of the two types of resistance has now been established. Crossing resistant and susceptible *A. gambiae* produces a hybrid which is intermediate in resistance (some thirty times) to dieldrin. By a simple technique of confining the mosquitoes for a given time to filter paper impregnated with insecticides in solution in a non-volatile oil, it has been found possible to separate susceptible, hybrid and resistant *A. gambiae* by using two different concentrations of insecticide. Of these two discriminating dosages, the lower kills all susceptibles but not hybrids, nor resistants, and the higher kills all hybrids (and susceptibles) but not resistants. Interbreeding the hybrids, and exposing the offspring to these two dosages, has produced a 25 per cent. kill at the lower one, and a 75 per cent. kill at the higher one, showing a simple sort-out into one susceptible, two hybrids and one resistant—the expected proportions where a single Mendelian character is involved. Further, backcrossing the hybrids to the parent susceptible and resistant strains showed a 1 : 1 ratio of susceptibles and hybrids in the offspring where the cross was made to the susceptible strain, and of hybrids and resistants where made to the resistant strain. Such a pattern of resistance is shown diagrammatically in Fig. 1.

The inheritance of DDT-resistance in *A. sundaicus* was similarly shown to be monofactorial, though here the hybrid was virtually as susceptible as the susceptible strain —i.e., the gene for resistance is recessive (while that in *A. gambiae* is semi-dominant). Here only one discriminating dose was possible, *viz*., one killing all susceptibles and hybrids, but leaving resistants unharmed. Exposing the interbred hybrids to this dosage results in a 75 per cent. kill, the 3 : 1 ratio of monofactorial inheritance where the hybrid resembles one of the pure strains. The offspring of the backcross of the hybrid to the resistant parent show a 50 per cent. mortality when exposed to the discriminating dosage, while the offspring of the backcross to the susceptible parent show 100 per cent. mortality. This pattern of inheritance is shown in Fig. 2.

The fact that the hybrid *A. sundaicus* is susceptible may explain the comparatively slow appearance of DDT-resistance in the field compared with dieldrin-resistance, where the hybrid itself is resistant; until hybrid mates with hybrid pure resistant individuals will not be produced. DDT-resistance did not show itself for two or three years after the start of DDT-spraying in Java, while dieldrin-resistance in *A. gambiae* in Northern Nigeria appeared only one year after dieldrin was first used for house-spraying.

The knowledge gained from these studies can, it is now thought, be usefully applied in the field for the detection of incipient resistance, possibly before the transmission of the disease recurs, so that a rapid change over of insecticides can be made (assuming that resistance to both DDT and dieldrin or BHC is not present). By exposing mosquitoes from the suspected area to the discriminating dosages, and rearing from the survivors, the type of resistance can be definitely established. For example, if resistance is present and of the type described for *A. gambiae*, a survivor from the lower discriminating dosage may be either hybrid or resistant. If hybrid, and previously mated with a susceptible, the offspring exposed to the same dosage will show a 50 per cent. mortality. If previously mated with a hybrid a 25 per cent. mortality will be shown in the offspring, and if mated with a resistant, or if the survivor is resistant mated with any of the three types, no mortality will be shown in the offspring.

If resistance is of the type shown in *A. sundaicus* the survivor from the discriminating dosage will be a pure resistant individual. If previously mated with a resistant no mortality will ensue in the offspring when exposed to the same dosage, and if mated with a hybrid a 50 per cent. mortality will be shown. If the previous mating was with a susceptible, however, the offspring will show a complete kill and it might be thought that no resistance is present and that the surviving mosquito was at the extreme range of normal susceptibility. To verify this it would be necessary to interbreed some of these offspring, and produce a second generation. If resistance is present these individuals will show a 75 per cent. mortality when exposed to the discriminating dosage.

One thing is clear now that the inherent nature of resistance is established, and that is that the higher the selection pressure, the quicker any resistance present in the population will appear. Thus a more efficient insecticide or a higher dosage or a combined attack on both larvae and adults could all increase the speed of selection. Conversely, a less efficient insecticide, or a lower dosage, or a partial attack only on the insect population would delay the appearance of resistance, though of course, such incomplete measures might not achieve the purpose of disease control. The habits of the mosquitoes themselves may also delay the appearance of resistance. If, for instance, the species is one that bites man relatively infrequently, and rests only occasionally and for short periods in houses, selection will be limited. This may account for the absence so far of records of resistance in such species as *A. culicifacies* in India, *A. maculatus* in Malaya and even *A. gambiae* in some parts of Africa. Alternatively, of course, the explanation may be simply that the gene for resistance is absent in these particular populations.

The problem of resistance is far from solved. An understanding of the physiological mechanisms involved may lead to a means of by-passing or upsetting them with other insecticides. Until such means are found, a practical approach to the prevention of the appearance of resistance might be in the use of mixtures of the two groups of chlorinated hydrocarbons, DDT and dieldrin or BHC. DDT is, however, irritating to mosquitoes, and may cause them to leave a treated surface before they pick up a lethal dosage. In a mixture this irritant property may cause exit before a lethal amount of the second insecticide is acquired. This is less likely to happen if the second insecticide is BHC, than if dieldrin is used, as the former, though less persistent than the latter, is nevertheless quicker-acting.

Rothamsted's New Director

This month, October 1958, Mr. F. C. Bawden, M.A., F.R.S., international authority on plant virus diseases, succeeds Sir William Ogg as Director of Rothamsted Experimental Station. Sir William has been Director since 1943.

Appointed to the scientific staff of Rothamsted as virus physiologist in 1936, four years later Mr. Bawden became head of the plant pathology department—a position he has held until now—and he has been a deputy director of the station since 1950.

Frederick Charles Bawden was born at North Tawton, Devon, in 1908. He entered Emmanuel College, Cambridge, in 1926, where he became an exhibitioner, scholar and prizeman. After being placed in the First Class of the Natural Sciences Tripos, he read for the Diploma in Agricultural Science, which he obtained in 1930. That year he became a research assistant to Dr. R. N. Salaman at the Potato Virus Research Station (now the Agricultural Research Council's Virus Research Unit) where he remained for six years.

During this time Bawden was principally engaged in devising methods for diagnosing the various virus diseases of the potato crop and, in particular, demonstrated the value of the serological techniques now so widely used to test for the presence of viruses. While at Cambridge he also began his collaboration with N. W. Pirie on the purification and properties of viruses, which has continued ever since (Pirie came to Rothamsted in 1940 and is now head of the biochemistry department). Their work showed several of the plant viruses to be ribose nucleoproteins, which they isolated in crystalline, or liquid crystalline, forms, and completely changed ideas about the nature of viruses, which until then were generally thought to resemble parasitic organisms.

In 1940, four years after his appointment to the scientific staff at Rothamsted, Bawden became head of the plant pathology department. From that year his interest increasingly extended from research on the nature of viruses to studying the effect of the manner of cultivation of plants on their susceptibility to viruses, and to field problems connected with the spread and control of virus diseases. The fruits of the department's work on these subjects are now generally known: they are widely applied in the schemes for the production and certification of healthy stocks of potato and other vegetatively propagated crops, as well as in the increasing use of insecticides to control the aphid vectors of viruses.

In 1949, Bawden was elected F.R.S. and when the Royal Agricultural Society of England instituted its Research Medal in 1955 he was the first recipient.

In addition to about 100 papers on viruses, Bawden has written one major work on the subject, *Plant Viruses and Virus Diseases* (Chronica Botanica Company, Waltham, Mass., U.S.A.; 1939; revised 1943 and 1950) and also a valuable introduction to general plant pathology (*Plant Diseases*, Nelson, London; 1948; revised 1950).

The past 20 years have seen considerable changes in emphasis on the type of agricultural research at Rothamsted. Pre-eminently a centre for the study of soils and fertilisers since its foundation by Lawes in 1843, its work on pests and diseases has steadily increased and Rothamsted's biological departments have also achieved a status second to none.

The new Director is the first biologist to have been appointed to this post of supreme importance in agricultural research, succeeding, as he does, a line of world-famous soil scientists—Sir Daniel Hall, Sir John Russell and Sir William Ogg—at a time when it is being increasingly realised that future improvements in world crop production will depend at least as much on efficient control of plant pests and diseases as upon increased use of fertilisers and greater soil fertility. The appointment of Mr. Bawden to direct the work of Rothamsted is surely to be welcomed.

THE EFFECTS OF ALDRIN, DIELDRIN AND ENDRIN ON INSECT PARASITES AND PREDATORS

by **A. M. H. Sanger**

The Shell Petroleum Company, Ltd.

During the past few years much attention has been paid to the effect of insecticides on insect parasites and predators. It has been stated that the application of insecticides, by killing parasites and predators, may result in a resurgence or "flare back" of the pest concerned, or of secondary pests. It has also been said that the resistance problem may be aggravated if natural enemies of insects resistant to insecticides are exterminated.

RIPPER (30) estimates that more than two per cent. of the world pests (100 out of 5,000) have shown resurgences and that perhaps a quarter of this number have developed resistant strains. RIPPER admits that these failures of current chemical techniques are not important so far, but he poses the question: 'Should not chemical control, as it is practised today, be seen as a purely temporary palliative which may raise yields in the short run, but will over a period of years end by saddling agriculture with pests which it will be impossible to wipe out, so that yields will fall again?'

In agriculture, it is easy to create resurgences by applying the wrong insecticide at the wrong dosage rate at the wrong time, and the number of insect species involved in resurgences could probably be extended to include all cases where the insecticide eliminates the natural enemies without seriously affecting the hosts. In practice, however, these instances will mainly occur when an insecticide is first tested in the field against a specific pest or pest complex, and such an insecticide, if resurgence is definitely proved, will usually be rejected. It may be for this reason that resurgences are not common phenomena affecting large crop areas; nevertheless, the problem is serious enough to warrant constant attention.

Resistance is quite another problem. If DAVIDSON'S findings (7, 8, 9) for *Anopheles* mosquitoes have wider significance it is by no means true to say that all insects will in time become resistant to insecticides, since many insect species may not have the specific gene which is responsible for the resistance of the insects to a specific insecticide. Furthermore, cross resistance may prove, at least for some insect species, to be limited to a distinct group of insecticides, leaving other insecticides as effective control agents. Of course, if natural enemies are eliminated selection pressure will increase and predisposed insects may form homozygous resistant strains in a shorter time; but for non-resistant strains of insects this is immaterial.

Parasites and Predators

At present, when the effects of insecticides on parasites and predators are discussed, there is a strong tendency to group all insecticides together, or to distinguish either between groups of insecticides such as the chlorinated hydrocarbons or the phosphorus compounds, or between insecticides with long and short residual effect. In fact most experience is based on the use of DDT and parathion, and to a limited extent on some of the systemic insecticides, and relatively little information is available on other insecticides. It therefore seems useful to examine the effects of aldrin, dieldrin and endrin on parasites and predators and on the occurrence of resurgences.

Table I
Parasites and predators on which the effects of aldrin, dieldrin and endrin have been studied

			Literature Ref.
Acarina	—*Laelaptidae*	—*Typhlodromus fallacis* (Gar.)	31
Coleoptera	—*Coccinellidae*	—*Ceratomegilla fuscilabris* (Muls.)	4, 6, 12, 17, 35, 36
		—*Coccinella 9-notata* (Hbst.)	
		—*Coleomegilla maculata* (Deg.)	
		—*Collops vittatus* (Say.)	
		—*Hippodamia convergens* (Guer.) and other spp.	
		—*Lindorus lophanthae* (Blaisd.)	
		—*Scymnus* spp.	
		—*Stethorus punctillum* (Wei.)	
Coleoptera	—*Cicindelidae*	—*Cicindela haemorrhagica* Lec.	13
		—*Cicindela pusilla imperfecta* Lec.	
Diptera	—*Tachinidae*	—*Exorista larvarum* (L.)	34
		—*Rileymyia adusta* (LW.)	
Heteroptera	—*Anthocoridae*	—*Orius insidiosus* (Say.) and other spp.	6, 36
Heteroptera	—*Lygaeidae*	—*Geocoris* spp.	6, 36
Heteroptera	—*Nabidae*	—*Nabis* spp.	6, 36
Hymenoptera	—*Eulophidae*	—*Aphelinus* (*Aphytis*) *chrysomphali* Merc.	4
Hymenoptera	—*Braconidae*	—*Opius* spp.	32, 33
Hymenoptera	—*Encyrtidae*	—*Metaphycus helvolus* (Comp.)	4
Neuroptera	—*Chrysopidae*	—*Chrysopa* spp.	6, 36

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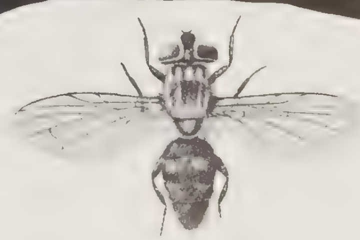
Anthocoris nemorum.



A tachinid fly, *Compsilura concinnata.*

A braconid fly, *Apanteles glomeratus.*

Stethorus punctillum (× 15).

The information in Table I is almost certainly incomplete since much unpublished material must exist; furthermore, data may have been published in local journals and reports which have escaped the author's notice.

Due to the limited amount of information available it is difficult to draw firm conclusions, but the indications are that aldrin, dieldrin and endrin (at dosages of 0.25-0.5 lb. per acre) are only moderately toxic to coccinellids and are in this respect less toxic than DDT (1-2 lb. per acre), BHC (0.25-0.5 lb. γ per acre), methoxychlor (0.75-1.5 lb. per acre), toxaphene (2-3 lb. per acre) or parathion (0.25-0.5 lb. per acre) and other phosphorus compounds; on the other hand, aldrin, dieldrin and endrin seem to be severely toxic to *Geocoris* and *Nabis* species. *Chrysopa* and *Orius* species are apparently tolerant to a wide range of insecticides including aldrin, dieldrin and endrin. In fact, if *Geocoris*, which also prey on *Orius*, are present populations of *Orius* may increase following insecticide applications.

Bartlett (4) has given some interesting data on the residual effect* of aldrin and dieldrin in relation to the toxicity of these insecticides to some parasites (*Aphytis*, *Metaphycus*) and predators (*Lindorus*). Unfortunately, no exact comparison is possible with other insecticides since aldrin and dieldrin were used at 0.5 lb. per acre and parathion and DDT at 2 and 4 lb. per acre respectively. However, if it is accepted that long term residues are independent of initial dosage rates (18), aldrin and dieldrin seem to be less dangerous to the natural enemies mentioned than parathion or DDT.

Another paper (19) of interest concerns the effect of endrin ground sprays for mouse control in orchards on overwintering parasites and predators.

Resurgences

A 'resurgence' as caused by insecticides may be defined as the build-up of an insect species, in greater numbers than before, after the application of an insecticide in comparison with an untreated control. According to Ripper (28), three hypotheses have been put forward to explain the phenomenon:—

(1) The reduction, with the pest, of natural enemies by the pesticide;

(2) Favourable influences of pesticides on phytophagous arthropods;

(3) The removal of competitive species.

To establish a resurgence it is necessary to carry out pre-treatment counts—because plot variation may be considerable—and post-treatment counts of both treated and untreated plots. The complexities of the build-up and decline of insect populations are so vast that mere 'observations' do not suffice to prove a resurgence. For instance, weather conditions alone may be responsible for a 'resurgence', and if this happens after insecticide treatment, the insecticide may be blamed. Whether or not a resurgence will result from an insecticide application will depend on many factors, not only on the differential toxicity of the insecticide to pests and natural enemies, but also on the rate of build-up of the insect species concerned. In some instances (2, 23) renewed build-up of natural enemies is so rapid after insecticide application that no resurgences occur even if the insecticide is not effective against the (secondary) pest concerned.

Table II
Pest species whose numbers have increased as a result of the application of aldrin, dieldrin or endrin

			Literature Ref.
Acarina	—*Tetranychidae*	—*Tetranychus bimaculatus* Haw.	40
		—*Tetranychus hicoriae* McG.	21
		—*Tetranychus pacificus* McG.	25, 26
Diptera	—*Agromyzidae*	—*Liriomyza subpusilla* (Frost)	37, 38
Homoptera	—*Aphidae*	—*Hyalopterus arundinis* (F)	27
		—*Macrosiphum pisi* (Kalt)	39
Homoptera	—*Cicadellidae*	—*Empoasca fabae* (Harris)	39
Homoptera	—*Coccidae*	—*Coccus hesperidum* L.	10
		—*Unaspis euonymi* (Comst.)	20
Lepidoptera	—*Gracilariidae*	—*Marmara* sp.	11
Lepidoptera	—*Tortricidae*	—*Amorbia emigratella* Busck	32
		—*Homona coffearia* Nietn.	3

If the above definition of a resurgence is taken into account, some cases regarding aldrin, dieldrin and endrin quoted in the literature (20, 40) become open to question. However, other cases definitely describe true resurgences, and in this connection work carried out by Michelbacher and co-workers (24, 25, 26) on melon insects is of great interest since it proves the importance of the timing of the insecticide application. In this particular case application of aldrin or dieldrin in July and August may result in serious mite damage, while application in September does not.

Timing of the application is also important when dieldrin is applied against *Xyleborus* on tea in Ceylon (3): if applied just after pruning no build-up of *Homona* will result.

Wilson and Davis (39) observed resurgences of *Empoasca fabae* (Harris) and *Macrosiphum pisi* (Kalt) when aldrin

* A residual effect may be physical (as measured by chemical analysis) or biological (as measured by its toxicity to a specific insect). In the latter case the residual effects may vary widely according to the test insects used. In the physical sense it is accepted that parathion has a shorter residual life than DDT, but biologically parathion may have a longer residual effect than DDT, e.g., regarding its action on *Grapholita* (1).

Ladybird (Coccinella *sp.*) *larvae feeding on aphids.*

Adult two-spot ladybirds feeding on aphids.

and dieldrin at a dosage of 0.5 lb. per acre were applied on alfalfa. This is somewhat surprising since aldrin and dieldrin are at least partially effective against these insect species and no other resurgences of these pests have, as far as is known, been reported.

Another interesting case (32) concerns the build-up of *Amorbia* in guava plantings due to the destruction of the *Iridiomyrmex* by dieldrin.

Finally, a paper which seems to disprove the theory that chlorinated hydrocarbons are always more dangerous than phosphorus compounds is that by Elmer *et al* (10) which shows that parathion (6 oz. per 100 gal. water, applied twice) is more likely to cause a resurgence of *Coccus hesperidum* L. on oranges than is aldrin or dieldrin (12 oz. per 100 gal. water, applied twice). In this connection it should be remembered that most resurgence cases have been reported after the use of DDT (28), but is this not due to the fact that DDT, being the first modern insecticide on the market, has been and still is applied against many insect species which it does not effectively control?

Discussion

Ripper (30) believes that the answer to the resurgence and resistance problem may lie in the use of selective insecticides. However, while this is a sound suggestion, the use of selective insecticides may be limited when a crop is attacked by more than one insect pest. Furthermore, the cost of selective insecticides is necessarily high—because of high development costs and limited commercial application—and may be prohibitive. Selective insecticides may become important in the future but at present no insecticide is really selective, with the possible exception of schradan.

Since selective insecticides are not available, the 'selective' application of the insecticides at present in use seems for the moment to be the best means of avoiding resurgences and, taking into account that insecticides should not be

used unless strictly necessary, the following means may be considered.

First, no insecticide gives 100 per cent. mortality of all insect species in the field, and the choice of the insecticide offers a first means of selective insect control. Secondly, since the immediate toxicity of an insecticide to insects is closely correlated with dosage rate, the lower the dosage rate used the more selective an insecticide will be. Taking these first two points together, although DDT at 2 lb. per acre and parathion at 0.25 lb. per acre will be cheaper than endrin at 0.25-0.5 lb. per acre, endrin (assuming that it controls the insect pest concerned at this rate) will be more selective than either DDT or parathion since both insecticides in this case will act as 'blanket' insecticides—DDT due to a high dosage rate and parathion on account of its great inherent toxicity to insects.

Thirdly, since life cycles of hosts and their natural enemies do not necessarily coincide, proper timing of the application forms another selective approach. Fourthly, the method of application has some bearing on the problem. Systemic insecticides applied to the soil or tree trunks may control specific foliage pests. As regards foliage applications, different formulations (dusts, high volume or low volume or mist spray) will probably have different effects on the pest-predator-parasite relationship. Little, however, is known on this subject. Bait sprays or sprays incorporating repellents may enhance the 'selectivity' of the insecticide, but here again, knowledge is scant. Fifthly, combined methods of biological and chemical control may prove to be very successful (Brunson and Allen (5)). As a variation of this approach, the use of dieldrin against ants which attend mealybugs may be mentioned.

It is certain that mixtures of insecticides, in particular when they are applied frequently, have disastrous effects on the natural enemy population (14, 15); in some cases, however (cotton, for example), this is unavoidable unless the farmer is content with greatly decreased returns. Cotton is not the only crop of which this is true. Marshall and Morgan (22) found that an orchard in British Columbia, unsprayed since its establishment, did not yield any fruit due to insect damage, although the number of economically injurious species was less than in commercial orchards. They comment: 'Hence, to control his arch enemy the codling moth, the British Columbia fruit grower, whether he likes the idea or not, must spray with DDT or methoxychlor, both of which are capable of upsetting the "biological balance" in his orchard. He must accept the fact that the use of either of these chlorinated hydrocarbons may in turn force the use of acaricides or aphicides'.

Among the many problems which have not been discussed in this article is the relative importance of parasites and predators, and its bearing on control measures. In this connection Glen (16) states: '[In Canadian orchards] in general parasites are most effective at densities of the pest species that are higher than can be tolerated economically, whereas general predators may be relatively influential at lower pest densities'. The merits of preventive and corrective spraying (for both of which advocates can be found) is a further aspect which it has not been possible to discuss here.

To answer Ripper's somewhat rhetorical question, quoted at the beginning of this article, as long as man remains unable to eradicate insect pests, he will not be able to eradicate their natural enemies. If strains of resistant insect pests develop, it is likely that some of their natural enemies will also have developed resistance. In fact it might well be rewarding to investigate the possibility of the propagation and release of resistant strains of predators and parasites as a new approach to biological control.

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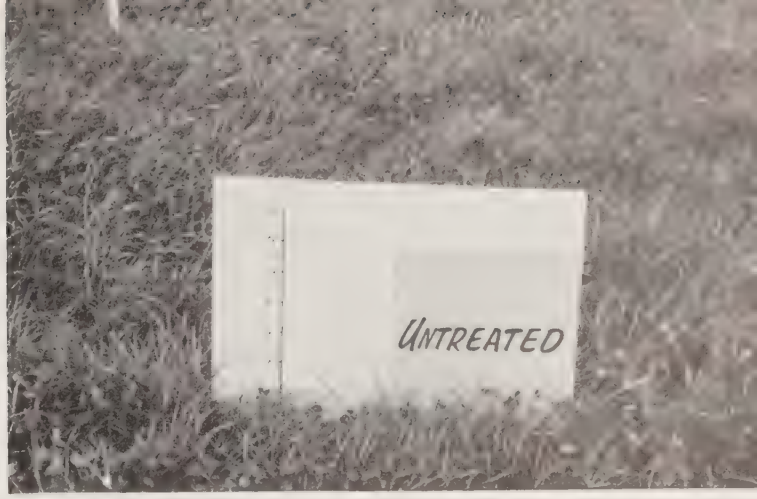
Grassland Productivity in the U.K.



A one-year ley, for hay, which has received no fertiliser top dressing. The height of the grass is 3 in.—6 in.

Rising costs, both on and off the farm, in the last decade have emphasised the need for an increasing efficiency of production in all aspects of British agriculture, but nowhere has this need been greater than in the livestock industry. It is not surprising, therefore, that considerable attention has been directed to the management and productivity of grassland in the U.K., as a means to combat the rising prices of animal feedstuffs and labour. For grass is still the cheapest food for livestock.

Since grass yields depend ultimately on the level of soil fertility, extensive fertiliser trials have been carried out, and the addition of nutrients to grassland has now been generally accepted as a necessity for intensive grassland production.

While many pastures benefit from, and require, regular applications of lime, phosphorus and potassium, there is little doubt that nitrogen supply is a major factor restricting production on the majority of grassland. This has been repeatedly shown in trials and demonstrations, but a recent survey of fertiliser practices in twelve districts of England and Wales indicates that nitrogen usage on grassland is still low.

Of the thirteen-and-a-half million acres of permanent grass, and six-and-a-half million acres of temporary grass in the U.K., only 21 per cent. and 35 per cent. respectively receive applications of fertiliser (these figures exclude a further sixteen-and-a-half million acres of rough grazing). Furthermore, the application rate of nitrogen on the areas fertilised is approximately 0.3 cwt. of nitrogen per acre—a figure that could with advantage to the farmer be increased, since it has been shown that economical increments in yield may be obtained at substantially higher rates of application.

It is thus apparent that there is still a large potential expansion for nitrogen usage on grassland, but this will be correlated with the fortunes of the individual farmer. The extra herbage produced by fertiliser application must be effectively transformed into livestock products. This implies a larger head of stock, greater storage facilities for hay and silage and probably increased mechanisation to ensure rapid conservation under optimum conditions.

In spite of these limitations, improved methods for grassland husbandry combined with a realistic fertiliser programme will help to produce a greater return at lower cost, and it is certain that nitrogen will play an increasingly important role as management becomes more intensive.

—W.N.M.F.

Part of the field shown above; it has received a top dressing of nitrogen as shown on the board. The height of the grass is 15 in.—18 in.

A nitrogen fertiliser demonstration showing differences in quality and weight of herbage between the treated and untreated grass.

A view of Woodstock Agricultural Research Centre showing, on the left, the administrative block, in the centre, the chemical synthesis laboratory (the autoclave can be seen in the foreground), and on the right, the biology laboratory. Opposite: The exterior of Modesto Agricultural Laboratory.

Shell in Agricultural Research

Before the last war the interest of the Royal Dutch/Shell Group in chemicals for the land was very largely centred on the widespread horticultural use of mineral oils. These were employed as carriers and toxic agents in fruit and anti-fly sprays. Equally important was the Group's activity during the nineteen-thirties in the fight against malaria, when pioneer work was done on the application of petroleum oils as mosquito larvicides.

By 1945 the agricultural—and public health—chemical interests of the Group were reaching a stage at which research facilities beyond those available at Amsterdam and at Emeryville (USA) would very soon be required, and that year two new agricultural research stations were set up. One of these was in England—at Woodstock Farm, near Sittingbourne—and one was in the United States—at Modesto, California. Both stations were set in the middle of farms which could be used for testing out the new products which would eventually be placed on the market.

Some three years ago extensive new laboratories were brought into use at Woodstock, and more recently the Modesto station has been developed to provide three times its original laboratory space. In view of this expansion it is opportune to review Shell's agricultural research facilities on both sides of the Atlantic.

At Woodstock the laboratories and other buildings connected with research cover about 25,000 sq. ft., and there are about 4,600 sq. ft. of glasshouses, equipped to provide temperatures and humidities simulating the climates of almost every country in the world. An engineering workshop is in constant use for the building of experimental apparatus for use in both field and laboratory. The station's 250-acre farm provides facilities for testing both new and established agricultural products.

The buildings at Modesto occupy a total of 50,000 sq. ft. of floor space, including library and administrative offices, and there is an experimental farm of over 140 acres. As at Woodstock, an engineering section develops the special equipment required for testing new—and established—chemical products.

Broadly, the functions of Woodstock and Modesto, and their facilities, are very similar. At both centres the work is divided into the search for new agricultural chemicals, the testing and development of new products, and the improvement of established chemicals and of new uses for them. As an example of the type of work for which these stations are equipped, let us consider the research involved in producing a new pesticide at Woodstock.

Research is initiated in the organic synthesis laboratory, where new chemical compounds are produced. The synthesis of these compounds is based on theories of how, by

Woodstock—an entomologist renews the water supply in the locust breeding cages.

Woodstock—a mechanical (vacuum) seed counter used in the plant physiology laboratory.

Woodstock—a research worker carries out a micro-bioassay test for the determination of micro-quantities of insecticide.

introducing a suitable chemical into the cells of plants or animals, their metabolic processes can be upset. Many of the chemicals produced have never been made before, and considerable research may be needed for their preparation: it is one thing to prepare a compound 'on paper' but often quite another actually to synthesise it. Once it is synthesised, if the new compound shows sufficient biological activity, a series of related compounds will be prepared in order to discover how changes in molecular structure may affect this activity.

For the initial biological tests about 5 gm., and for initial field tests 10 lb. or more of a new chemical are required. Provision of the quantity needed for field testing often involves further research on methods of preparation.

Closely associated with the work of the synthesis laboratory is that of the chemical analysis laboratory. Physical or chemical analysis enters into every phase of the work at Woodstock: it confirms the structure and purity of newly synthesised chemicals; it controls the composition and stability of experimental formulations and it determines the chemical residues which remain in or on treated plants and in animal organs.

The estimation of chemical residues entails much research, as the accuracy required is in the neighbourhood of one-tenth p.p.m., and established analytical methods are often not directly applicable. Each type of crop, moreover, presents a distinct and individual problem.

The second phase in research on new compounds consists in screening in the biological laboratories. Newly synthesised compounds are passed to the appropriate laboratory for assessment of their value as insecticides, fungicides or weedkillers. In the entomological laboratories new chemicals are tested under controlled conditions for biological activity against insects, and the factors which influence their performance are studied. One important phase of the work is the use of susceptible strains of insect for bio-assay, a technique which can be used to estimate residues too small for determination by chemical analysis.

The laboratories contain six constant-temperature rooms where experiments can be undertaken and insects bred in conditions of controlled temperature and humidity. In these rooms, and in one of the glasshouses, strains of a number of insect species are permanently maintained for testing purposes and other species are bred as the work demands. The chemicals under test are applied to these insects, and to plants, with special types of precision sprayers whose use ensures that the exact dosage of insecticide applied can be repeated whenever necessary.

The initial tests on weedkillers are carried out in the plant physiology laboratory, whose equipment includes two constant-temperature rooms. Most of the experiments carried out in this laboratory demand only simple apparatus, but the work has led to the development of techniques by which the effect of chemicals can be observed on single plant cells. Work on weedkillers calls for large stocks of weed seeds, and these are collected and germinated in the laboratory.

Newly synthesised fungicides are tested in the plant

pathology laboratory, where cultures of plant fungi, such as *Alternaria*, which causes early blight in potatoes and tomatoes, are permanently maintained in artificial media to provide a reservoir of fungal diseases ready for laboratory testing at any time of the year.

New compounds which show sufficient promise during laboratory testing are passed on for further trials in the glasshouses where it is possible to test a chemical against pests or diseases in controlled conditions independent of climate and season. One of these houses is given over entirely to the propagation of test plants—of which at least 2,000 are needed every week—and others are employed for insecticide, fungicide and weedkiller tests.

The compounds which have survived the laboratory and glasshouse tests now enter the application phase of development. Very few chemicals can be applied in the form in which they are originally produced as their high concentration necessitates their dispersal in a carrier for application; they therefore have to be formulated into products which are suitable for use in the field. Research into the physico-chemical relationships which influence the field performance of chemicals, and the formulation of new products, is carried out in the chemical formulation laboratory. In this laboratory also are developed the formulation manufacturing specifications and control tests which are used in full-scale production.

Meanwhile, a variety of problems connected with the eventual launching of the new product on the market has to be considered. Are raw materials for bulk manufacture available? Can the product be manufactured to sell at an economic price to the user? What will the patent position be? Can the product be stored over long periods without deterioration? Will it corrode metal containers? And, particularly important, will it leave undesirable toxic residues on crops for human—or animal—consumption?

Assuming that satisfactory answers can be found to all these questions, the new product (by now formulated) will undergo several years of field trials, not only at Woodstock but in many parts of the world. During this period the behaviour of the product will be studied under every possible condition, so that by the time these large-scale trials have been completed a very thorough knowledge of its properties will have been acquired, enabling the fullest advice to be given on its use when it is finally placed on the market.

The development of new products, of course, is only one part of the work done at Woodstock (and at Modesto) and, as has already been mentioned, research on the application of established pesticides is constantly being carried on.

While at Woodstock and Modesto the facilities are in general similar, certain differences in emphasis do exist. Aspects of applied research which are of particular importance at Modesto are work on the control of plant parasitic nematodes (the soil fumigants, D-D and Nemagon were developed by Modesto nematologists), on the development of soil fungicides, and on the study of plant nutrition. At Woodstock, special emphasis has been placed on the search for new foliage fungicides, insecticide formulations for locust control and the control of vectors of human disease.

Modesto—in one of the new glasshouses which were part of the recent extension, pinto beans are being test sprayed for root rot control.

Modesto—a residue analysis test being carried out on the new insecticide, Phosdrin.

Aquatic Weed Control

by **K. Wilson-Jones,** *formerly Senior Economic Botanist, Gezira Research Farm, Sudan.*

Weeds of water are a widespread but relatively little studied problem. This is partly due to the fact that water is seldom the direct responsibility of any single owner or organisation, and partly to the fact that on average the value of water, even in the more highly developed countries, is low compared with that of land. On the other hand, the difficulties —and therefore costs—of weed control in water are enormously higher than on dry land.

In general, one can distinguish three broad types of water in which weeds grow and may give rise to trouble of one sort or another:—

(1) Irrigation systems, where water is distributed *from* a main trunk canal or channel, through branching distributaries of steadily decreasing size, and finally through field outlets on to the land;

(2) Drainage, including natural river systems, where water emerges from large numbers of tributaries which join together to form the main trunks. This situation, though geometrically similar to (1), is dynamically its exact opposite;

(3) Ponds and lakes, natural or artificial, in which only slow flow of water occurs.

In the first and second of these categories the effect of weeds is principally felt in restriction of the cross-section of channel which is available for water flow, resulting in flooding near the source and restriction of flow lower downstream. Incidental effects are to be found on fish life and on navigation, though constant navigation has in certain circumstances the valuable effect of keeping water channels open. In the case of ponds and lakes the principal effects of weeds are on amenity rather than on engineering grounds, including the imparting of 'off-flavours' to water supplies, the restriction of fishing, and the provision of harbourages for insect breeding. In this article it is proposed to deal principally with the problems of weeds in irrigation and drainage systems.

The weeds of these waters can be classified according to their habits, which vary from those of plants rooted in the mud of the water's edge, through those of the rooted but immersed pond weeds, to those which are fully free-floating, such as the duckweeds. They include representatives of almost all the major groups of plants, with the exception of the gymnosperms, but the principal offenders are the flowering plants and algae (with the important exception of *Salvinia*, a floating water fern which has become widespread in recent years in Ceylon). One of the simplest and most arbitrary, and at the same time most descriptive, habit classifications is that into 'fixed' and 'floating' plants. (The former are those rooted below water level, but otherwise subaerial; the latter are plants which are more or less totally immersed in the water, except for a certain number of leaves or flowers which are subaerial.) The 'floating' group can if necessary be further subdivided into 'rooted' and 'free floating' weeds.

Various schemes have been devised, particularly in urban areas, for dealing with the problems of free flow of water. The most obvious is the provision of covered channels—i.e. pipe mains and sewers—in which no plant life is possible because of the absence of light. A half-way measure towards this is the provision of open but concrete-lined or cement-lined water channels, which discourage weed growth by absence of points of attachment, assisted usually by a swifter (because more friction-free) water flow. These measures are usually expensive in first cost and are only feasible in special areas. More frequently, simple earth channels have to be used, the clay in whose bottom becomes, in time, more or less impervious to water. These form an ideal habitat for weeds in water.

Fixed Weeds

Fixed weeds are usually controlled by cutting or by the use of herbicide sprays, applied from the banks. With some species, such as tufted rushes, and where labour is cheap, it may be possible to uproot the plants bodily by hand and leave them to die on the banks. In many cases, however, stoloniferous grasses of the couch type form a mat which grows down below the water level and may completely colonise the bed of a shallow water channel; this problem can be very serious in an emergency, for not until the water level has risen above the top of the grass stems can the normal rate of flow be resumed.

In these cases it is often found that by redesigning and digging out the water channel so as to provide a narrower and deeper stream, with the banks as steep as possible at and below the water line, the encroachment by grasses can be prevented. Herbs and tree seedlings can usually be suppressed by animal grazing, mowing and the use of herbicides of the 2,4-D and 2,4,5-T type, or by combinations of

A weed cutting launch, with V-shaped blade in the foreground, and paddle propulsion.

The weed cutting launch in reverse operation: the launch is steered by turning the paddle unit.

these treatments. Fixed weeds growing in water are thus largely a matter for the engineer, and those growing on the dry land are one falling within the general province of management of uncropped land.

Floating Weeds

Mechanical methods of control of floating weeds are numerous, and range from the manual use of long-handled rakes by men either in the water or on the banks, to powered boats specially equipped with cutting knives, and cutting chains drawn by men or tractors on either side of the channel. Fundamentally, all these methods are similar in principle. The device, whatever it is, cuts or breaks off the weeds at or about mud level, and the weeds, which normally contain air cavities, float to the surface and are collected, usually at some convenient point such as a weir or regulator, downstream.

Potamogeton spp., *Najas* spp., *Elodea*, *Ceratophyllum*, *Ottelia*, etc., all behave satisfactorily in this manner, but *Chara*, a dendritic alga which grows as a mat at the bottom, contains large calcareous inclusions and will not float. Where the latter occurs, mechanical control has to take the form of actual dredging. Fortunately, though widespread all over the world, *Chara* species tend to be local in occurrence and confined to the less acid waters. They are also intolerant of suspended silt.

Mechanical methods will control floating weeds in the sense of preventing their blocking the flow of water, but can probably never eradicate them entirely. Further, small broken pieces of weed will float with the current until they lodge, and will then root and set up a fresh infestation in their new environment, thus spreading the infestation. Plants which are allowed to seed between mechanical clearances will also give rise to fresh infestation downstream. An interesting experiment was carried out by ANDREWS (1) in the canals of the Sudan Gezira, in which the weeding cycle was speeded up with the object of preventing seeding of the weeds. Under the tropical conditions of the experiment this at first involved clearance every ten days, which not only succeeded in its primary object but weakened the plants—mainly *Potamogeton* spp. and *Najas pectinata*—to such an extent as to enable the inter-weeding period to be extended to fourteen days, with appreciable reduction of both weed growth and costs of clearance. Unfortunately, the difficulty of supervision, due to the small scattered teams employed, prevented the adoption of the method as standard practice.

The possibility of killing water weeds by periodically drying out the water channels has been investigated in many parts of the world. Unfortunately, many species of floating weeds, including *Potamogeton* spp., are rhizomatous as well as being prolific seed producers, and so in addition to encouraging the growth of fixed weeds in the bed of the half-dry water course, regrowth of the floating plant is rapid.

Certain vegetarian species of fish have been claimed to be of value in eating aquatic vegetation, and it has been reported that *Tilapia melanopheura*, one of the fishes normally introduced into fish ponds in the Belgian Congo, is put there primarily for this purpose. The same species has been introduced into wells and water holes in a number of oases in the Western Desert of Egypt, also with marked improvement in the condition of the water. However, although the species was introduced into one of the canals of the Sudan Gezira in 1952 with apparent temporary success in reducing weed growth during the following year, no individuals could be recovered at the end of the season and the reduction in weed had to be considered fortuitous. It was assumed that all the fish had either migrated upstream or succumbed to predators. However, in small tropical ponds, and in the absence of efficient predators, the method is well worth trial.

A further type of biological control of weeds in fishponds has been investigated by the U.S. Fish and Wildlife Service. This consists in the addition of heavy doses of fertiliser, which increases the growth of plankton to such a point that insufficient light is transmitted by the water to allow growth of aquatics from the bottom. As, at the same time, the plankton is furnishing rich food for the fish, the method is economic—though this is only so in the more highly developed regions of the world, where proper exploitation of the fish is possible.

The remaining possibility of control is the chemical one. This too has its drawbacks, but in the long run it is probably the only method capable of giving eradication—although it must be admitted that to date there are no instances of its having repeatably done so. The writer spent a number of years investigating possible chemical methods in the

Experimental application of 2,4-D 5 per cent. dust to a canal. The men's passage through the water has the necessary mixing effect.

A section of the canal shown in the picture on the left, photographed three weeks after treatment. Masses of dying weed (chiefly Ottelia alismoides *and* Vallisneria spiralis*) have broken loose and are floating.*

Sudan, and the comments below should be considered mainly in the light of tropical irrigation systems.

'Hormone' weedkillers

Unrooted sprigs of many water weeds are killed in the laboratory by a few days' exposure to concentrations of the order of 10 p.p.m. acid equivalent of sodium 2,4-D or MCPA (2). However, rooted plants of *Najas pectinata* and certain *Potamogeton* species growing in soil at the bottom of aquaria required exposures to 10 p.p.m. for periods of up to three weeks for death to be complete. As in most irrigation systems there is an annual 'shut-down', for agricultural reasons, experiments have been carried out using massive applications of hormone-type weedkillers of the order of 10 p.p.m. and above to the water ponded at these times. Under Sudan conditions complete clearance of all floating weeds, and many sedges, occurred for periods of up to nine months; but regrowth, when it eventually occurred, was apparently from rhizomes, as well as seeds, which had survived the treatment. Biological tests showed that the weedkiller persisted in the water for less than five weeks after application. Anomalies occurred, however, and in small experimental ponds of 50-150 cu. m. capacity, using powder formulations, complete and permanent clearance was obtained. When the chemical was added as solution, either alkali metal or amine salt, or as an emulsion, control was seldom or never complete even immediately following treatment. Sodium 2,4-D was normally applied as a dry powder in most of the experiments, but it seemed, from a consideration of the data, that the least soluble formulations used, such as a lime-based MCPA or 2,4-D dust or methoxone (free acid) wettable powder gave the most consistent results. This is perhaps to be expected since a dust falling through the water and lodging on the plants will produce a higher local concentration than a uniformly distributed solution of 10 p.p.m.

Emulsified solvents

Two principal types of emulsified solvent have been tested, and are at present in use (mainly in the USA) (3) for aquatic weed control; the first is partially chlorinated (mostly trichloro) hexene ('Benochlor'); the second is the 'solvent naphtha' type containing a high proportion of aromatics. Both are applied in a similar manner, by spraying a concentrated emulsion of the solvent through underwater jets into the stream, so as to produce a concentration of about 150 p.p.m. of the former or 300 p.p.m. of the latter over a period of about one hour. The white 'blanket' in the water can be followed downstream, and 'booster' applications at half strength given as it begins to thin out, due to absorption on the vegetation. The booster doses are recommended at maximum intervals of one-and-a-half hours or three-quarters of a mile, whichever is the less. It will be seen that only where water flow is rapid and the channels narrow can this method be economic, and it has been tried and abandoned for this reason in the Sudan.

The most important difference between the two chemicals —apart from that of costs—relates to the different densities of the solvents. When the emulsion eventually breaks, the naphthas rise to the surface, whereas in the case of the chlorinated compounds, they sink. Towards the end of a treated reach, therefore, the kill of weeds in the case of the naphthas is confined to the parts nearest the surface; regrowth is consequently rapid.

It should be remembered that these solvents are all toxic to fish life, and for this reason they should be used with care. On the other hand, animals will normally refuse to drink treated water, and it has been shown that the water can safely be used for irrigation provided that the crop plants are not flooded.

Copper Sulphate

From experiments (4) in the control of snail vectors of bilharzia, using continuous applications of hydrated copper sulphate of the order of 1 p.p.m. to irrigation channels, it has been found that under tropical conditions a very satisfactory control of angiospermic weeds, as well as of snails and algae, can be obtained. It seems apparent that at concentrations below this level, copper salts are not precipitated from the water and can remain in solution to exert a toxic action far downstream. Unpublished experiments in the Sudan have shown that concentrations as low as 0.5 p.p.m., if continuously maintained, will give practical control of *Najas* and *Potamogeton* species for distances of at least 20 km. below the point of application. Parallel work in the USA (5) has resulted in the Los Angeles City Water Undertaking adopting a policy of maintaining a concentration of 1 p.p.m. in its reservoirs, with consider-

An irrigation canal, showing medium to heavy weed infestation, mainly Potamogeton nordosus, *floating at the surface.*

Emulsified aromatic solvent being applied to a canal; note the white 'blanket' of treated water appearing just below the point of application.

able improvement both in the quality of the water and in the ease of maintenance of the supply channels.

Mention must also be made of experiments which have been carried out in attempts to 'sterilise' the beds of water channels. These have mostly taken the form of drying out the channels, followed by weedkiller applications, sometimes accompanied by ploughing. None so far seems to have yielded results commensurate with the expense, though if a sufficiently powerful herbicide could be used, the method might be the most promising. Difficulties are, first, that many of the weed seeds pass through an indefinitely long dormant period, during which they are inaccessible to the action of the chemical; secondly, that seepage in the channel bed will always tend to carry soluble herbicides away from the rooting zone; and thirdly, that the channel bed, always under water and high in humus content, will furnish an excellent medium for the biological breakdown of the chemical.

Special Weed Problems

Most of the problems discussed have been those of mixed weed infestations. However, in a few instances single weed species have multiplied to such an extent as to form a special problem by themselves. The first recorded one is that of the Canadian pondweed, *Elodea canadensis*, which was introduced into the United Kingdom during the nineteenth century, and which spread vegetatively throughout the English canal systems within a few years, blocking navigation and ruining inland fishing. Now, possibly as a result of the establishment of ecological checks on its increase, it has ceased to be so aggressive and takes its place among the *Potamogeton* species and other 'nuisance' weeds.

The second of these single weed species is *Eichornia crassipes*, the water hyacinth, which is tropical. This is a free floating weed, with emergent leaves whose petioles are modified into 'floats'. It has spread from the Amazon (assisted by man because of its ornamental value) into almost the whole of the Old World tropics and the warmer parts of North America. Wherever it has gone, the story has been the same—of navigation impeded, drains and irrigation ditches blocked, and of mosquito breeding in the still water between the floating plants. Spectacular, but temporary, control has been achieved by the use of 2,4-D sprayed from aircraft (6); but the species is still spreading, and has now entered East Africa via the Congo Basin.*

Salvinia auriculata was introduced into Ceylon (for university research purposes) in 1939, from the Royal Botanic Gardens, Calcutta. It, like *Eichornia*, is a native of the New World. By 1956, it had become a major pest all along the Western coast of the island, blocking irrigation canals and water supplies, including power station intakes. Where the weed escapes into paddy fields it can choke the young rice crop, and extensive work has been carried out with a view to controlling it by various means. Here, too, as in the case of *Eichornia*, only chemicals have given any promise of success, and in this case emulsions of mineral oil fortified with pentachlorophenol have been found most effective. Active campaigns of *Salvinia* eradication by this method have been in progress since 1955 (7).

In general, it may be said that where a single-weed problem exists, it is due to an introduced species colonising a new habitat. Probably, as in the case of *Elodea*, these species, after a number of years in a habitat, will acquire a group of parasites and predators which will eventually control them at a level lower than 'epidemic', but how long is required and whether that level will be acceptable to the users of the water is an open question.

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*Since this article was written, an outbreak of water hyacinth, described as 'explosive', has been reported from the *Sudd* (great swamp) areas of the Southern Sudan (8).

A guide to insecticide formulations

by **J. W. Harrison**

The Shell Petroleum Company, Ltd.

Over a century ago the discovery was made that plant extracts such as pyrethrum and nicotine, and inorganic salts such as lead arsenate, were lethal to insects. From these beginnings very little progress was made in the development of insecticides until the discovery of DDT in 1939. This discovery marked the beginning of a new era in the development of synthetic contact and stomach insecticides (which now include aldrin, dieldrin, endrin, BHC, heptachlor, DDT, chlordane, etc.) and the application of these insecticides presented a number of new problems to the formulation chemist.

As very small amounts of pesticides are highly toxic to insects they have to be made available to the user in a dilute form, or, alternatively, in a relatively concentrated form which can be easily diluted before use. The processes involved in converting the active compound into such forms are known commonly as formulation. The selection of the particular formulation to be used depends upon a number of factors such as the life cycle and habitat of the pest to be controlled, the prevailing climatic conditions, and the availability of equipment and suitable diluents. Where, for instance, water is not available the use of emulsions and water dispersible powders is precluded.

Most insecticides are supplied as both liquid and solid formulations; these include solutions, emulsifiable concen-

trates, water dispersible powders, dust concentrates, field strength dusts and granules.

Solutions

The simplest of all formulations is a solution of the insecticide in a solvent, but even here the selection of a suitable solvent presents a number of problems, and the choice may be governed by any of the following factors: price; availability; phytotoxicity; flash-point; volatility; viscosity; odour; colour; miscibility with other solvents or oils which may subsequently be required for dilution; and, of course, the ability of the solvent to dissolve a sufficient quantity of the insecticide.

Let us consider some of these factors. A particular solvent may possess adequate solvent power, but its flash-point may be too low to permit economical transport (due to high freight rates) or to be safe for use in confined spaces or in certain types of equipment. The viscosity of a solvent is a measure of its flow properties, and indirectly of the particle size distribution of the sprayed droplets of the formulation. The volatility of the solvent also affects the particle size of spray droplets, since, in the extreme case of the solvent being completely evaporated, the resultant deposit will consist of solid particles of insecticide instead of oil droplets. In cases where liquid formulations are sprayed either in the form of a fine mist, which results in a relatively large surface area exposed to the atmosphere, or where the droplets are exposed to the atmosphere for long periods, as in aerial spraying, volatile liquids will evaporate and thereby affect the nature of the final deposit. On the other hand, a solvent possessing a very low volatility is likely to remain on the sprayed surface for longer periods, and in the case of foliage this may give rise to scorching. The odour and colour of a solvent may often be important in relation to its suitability for domestic spraying.

Due consideration of all these factors generally leads to the selection of an organic solvent such as xylene, coal tar naphthas, petroleum oil fractions and various other aromatic hydrocarbon solvents, for the formulation of insecticide solutions.

Generally speaking, the solubility of those insecticides which are commonly referred to as the chlorinated hydrocarbons (e.g., aldrin, dieldrin, endrin, DDT and BHC) is higher in solvents containing a high percentage of aromatic compounds than in those containing only a low percentage of aromatics. As damage to plants is caused chiefly by aromatic compounds, it follows that the best solvents may also be the most phytotoxic, unless they are sufficiently volatile to evaporate relatively quickly from the plant surface. In localities where transportation is not a problem and water is not readily available for the preparation of dilute emulsions, solutions containing, say, only 5 per cent. dieldrin in relatively non-phytotoxic oils may be used.

In some circumstances—for instance, in anti-locust spraying—where crop damage is not important, the choice of solvent is likely to be governed by the viscosity of the solvent, and by its volatility and solvent power. The latter factor is of particular importance in relation to costs of transport and application.

Emulsifiable concentrates

An insecticide emulsifiable concentrate is, in its simplest form, a concentrated solution of an insecticide to which an emulsifier has been added. One of the purposes of this type of formulation is to provide the user with the insecticide in a form which can be readily diluted with water. Apart from this obvious advantage, however, a properly designed emulsion possesses properties which are not found in other types of formulations, such as the ability to produce high initial deposits and complete coverage on waxy surfaces.

Briefly, an oil-in-water insecticide emulsion consists of small droplets of the insecticide-in-oil solution dispersed in a continuous water phase. Each droplet is surrounded by water and the emulsifying agents present so reduce the inter-facial surface tension between the oil and the water that the oil droplets are prevented from coalescing. In this state a good emulsion remains homogeneous and stable for some hours.

The addition of electrolytes, such as common salt or the inorganic salts which occur in hard water, may disturb the balance of the forces maintaining the equilibrium of an emulsion; the oil droplets will then coalesce and the emulsion will break to form a separate oil phase. For most applications this is an undesirable feature, as it is often necessary for an emulsion to remain stable for several hours. For example, if an emulsion were to break down completely during a crop spraying operation part of the crop would be sprayed with water containing no insecticide and part would be sprayed with an oil solution of the insecticide, which would probably cause scorching of the crop.

The formulation chemist has, on the other hand, to design an emulsion which will also break reasonably quickly on striking the sprayed surface. On water repellent surfaces, such as foliage, this will reduce the loss of insecticide in the 'run-off' and allow the oil droplets and insecticide to remain on the surface where they should, ideally, coalesce to form a thin surface film. One of the problems in designing a satisfactory emulsion is to ensure that this coalescence does not give rise to scorching of the foliage or to other undesirable symptoms.

Solid formulations, like liquid formulations, are available both in forms which can be diluted with water (water-dispersible powders) and in forms for use where water is not available or its use is undesirable (field strength dusts, and granules). Field strength dusts are obtained by diluting a dust concentrate with a diluent such as talc, chalk, kaolin, bentonite, etc. A granular formulation is a coarse type of field strength dust.

Water-dispersible powders

As the name implies, a water-dispersible powder is one which will mix readily with water to form a dispersion or suspension. This type of formulation is prepared by absorbing a high concentration of the insecticide on to a suitable filler and adding a sufficient quantity of suspending, wetting and stabilising agents to give a product which after milling will remain in suspension under specific test conditions. It should be noted that the suspension properties of a

given product are liable to vary according to the temperature and hardness of the water which is used to prepare the suspension.

In some agricultural applications dispersible powders may be used interchangeably with emulsifiable concentrates, provided that the appropriate spraying equipment is available. It should be remembered, however, that a good emulsion will give better cover than a dispersible powder. For some applications a formulation containing an organic solvent cannot be used as it might cause damage to the crop or be otherwise disadvantageous—as, for instance, in the case of root dips for the protection of seedlings against soil pests. In this case a dispersible powder would be preferable to an emulsifiable concentrate because of the damage that would be caused to the young roots by the absorption of the solvent present in the emulsifiable concentrate.

For the deposition of insecticides on to porous surfaces, solutions and oil emulsions are unsuitable because the insecticide will migrate with the solvent away from the exposed surface. The mechanism by which this occurs is referred to as absorption or adsorption, depending on the particular physical forces involved (where it is not known which mechanism is operating the word 'sorption' is sometimes used to describe this phenomenon). Solid particles of insecticide present in water-dispersible powders are more likely to remain on the exposed surface of a porous material, which explains why water-dispersible powders are used on such a large scale to provide residual films of insecticides on the mud walls of native houses found in mosquito-infested areas.

Dust concentrates

Dust concentrates are powders consisting of fillers on which a high concentration of insecticide has been absorbed. They are manufactured by milling together the appropriate quantities of filler and insecticide, with any other ingredients, such as stabilising agents, which are necessary for the production of a stable product. Many fillers tend to catalyse the decomposition of insecticides, particularly the 'chlorinated hydrocarbons', and it is therefore necessary to test each filler which is to be used in conjunction with an insecticide to determine whether or not any decomposition is likely to take place during manufacture or while the dust is stored for long periods. Where a filler is found to cause decomposition of the insecticide the addition of a stabilising agent can often be used to overcome this disadvantage.

Dust concentrates are not, of course, applied undiluted: they are used simply as a convenient means of transporting the insecticide in a form in which it can be easily diluted by a local formulator.

Field strength dusts

Field strength dusts are prepared by diluting a dust concentrate with a convenient diluent. Diluents, like fillers, can cause the decomposition of insecticides and it is therefore necessary to test each diluent for this kind of catalytic activity. Usually, if required, a diluent can be deactivated before it is mixed with the insecticide.

Although field strength dusts are not generally preferred to emulsions for crop protection, their use is essential in districts where water is scarce, and where oil solutions cannot be used. They do not give the coverage and protection that can be obtained with emulsifiable concentrates and dispersible powders since the dust particles are more readily eroded.

In some cases it is desirable to use dusts, as, for example, in the use of dieldrin for the protection of rice and tobacco crops against foliage pests. In the case of tobacco, leaf that is used for cigar wrapping must be entirely free from insect damage: as the plants grow rapidly and new leaves are continuously appearing, they must be protected by weekly applications of insecticide, so that long periods of protection are not needed. Dusting will provide adequate protection for the required period, and as the dust particles are soon eroded there is little likelihood of significant residues remaining when the leaves are harvested.

In the case of rice, irrigation water is often drained into fish-inhabited lakes and rivers. If a dieldrin emulsion is used to protect the crop, the droplets containing dieldrin will disperse through the water and kill fish. But if a dust is used the dieldrin is not so readily dispersed since its solubility in water is only 0.05 p.p.m., and thus the damage to the fish is reduced.

Dusts are also useful when it is an advantage to be able to see whether a crop has been treated or not.

The properties of insecticide dusts can be varied slightly according to the particular use in view. Foliage dusts, for instance, must be sufficiently fine to allow the insecticide to be distributed without settling down too readily, whereas insecticide dusts which are intended for application to the soil may be relatively dense and contain coarser particles.

Granules

Granular formulations of insecticides generally contain a low concentration of the insecticide (up to 10 per cent. wt.) and are intended for application without further dilution. The granules are often impregnated with insecticide by spraying them with a solution of the insecticide in a solvent which will evaporate from the granules. Granular formulations are similar to field strength dusts, but they are primarily used in circumstances where other formulations would not be able to reach the site of pest infestation due to the presence of heavy protecting foliage. An example of this is provided by the European corn-borer (*Pyrausta nubilalis*), which for part of its life is protected by the leaf sheath. Endrin granules are able to penetrate this leaf sheath in a way that is not possible with an emulsion, dispersible powder or dust.

This article has dealt with the main types of insecticide formulation used, but no attempt has been made in this brief summary to enumerate either particular uses or the modifications which have been made by various formulators to meet specific problems. Examples of the formulations which have been evolved to meet special requirements are solid and liquid seed dressings, sheep dips and moth-proofing emulsions: all are based on the fundamental principles which it has been the object of this article to present.

SPRAYING OAKS IN PORTUGAL

In recent years the depredations of *Tortrix viridana*, the oak leaf roller, or 'burgo' as it is known in Portugal, have seriously affected production in that country of *Quercus ilex*, the Holm oak, a tree grown not only for its timber but also for its acorns, which are used for fattening pigs.

To be effective, spraying against *Tortrix* must be well timed: the insects must all have hatched, and most should be in the third instar; furthermore, the new oak leaves must not have started to grow. Spraying has therefore to be carried out during a limited period, and for this, the quick coverage which can be achieved with aircraft is invaluable.

In March and April this year a campaign against *T. viridana* was launched by the Portuguese Forestry Bureau, in which 7,000 ha. of oaks were sprayed from the air—5,300 ha. with endrin and 1,700 ha. with DDT. Endrin at 100gm. and DDT at 1.200 gm. per ha. both gave an excellent initial kill [the full effects had not been assessed at the time of going to press—Ed.]. The endrin was used as a solution in gas oil (0.5 kg. technical endrin, 2.0 l. blended hydrocarbon solvents and 97.5 l. gas oil), applied at 20 l. (100 gm. active material) per ha. The DDT was also used as a gas oil solution. For this operation, Piper Cub aircraft were employed, equipped with 420-litre spray tanks and fixed spray booms which gave a 20-metre wide swath.

The top picture shows spraying in progress; that in the middle shows an aircraft being replenished with endrin solution from the tanker at the landing strip; and in the bottom picture an aircraft is being flagged by a marker.

This picture shows how a water course can erode the soil to form ravines.

Soil and water conservation in Rhodesia

by **C. B. Metcalfe,** *Conservation and Extension Officer, Federal Department of Conservation and Extension, Southern Rhodesia.*

It is, perhaps, difficult for those who live in temperate climates to appreciate the significance which the word 'conservation' holds for the inhabitants of tropical and semi-tropical regions. Nevertheless, it is no exaggeration to say that today that word conveys to people in many parts of the world a choice between action and neglect which can spell hope or despair for the future.

Even in temperate climates, of course, soil and water conservation have their importance, for great harbours can silt up and droughts sometimes occur. But in temperate regions the rapid erosion of soil and the advance of deserts are far from being an ever-present spectre; the effects of erosion are present, but rarely spectacular, and cause and effect are not obviously connected. Here, in Rhodesia, though, cause and effect can be seen at the same time; rain falls and in a few minutes soil is on the move.

In the Rhodesias—as in many countries outside the temperate zones—a number of factors, each capable of causing erosion, can work together to result in hundreds of tons of top soil being stripped from every acre, and the scouring of great gullies deep into the subsoil. Early in the 1957 rains, thirteen inches of rain fell in one night on many farms in the area north of Salisbury, Southern Rhodesia, and tore away two inches of soil. Recovery from such damage will take a lifetime.

The annual rainfalls of eastern England and of the Highlands of Southern Rhodesia are similar, falling into the 20-40-inch category. But in the one case the rain falls in gentle showers throughout the year, enabling grasses to develop a thick turf; in these conditions humus accumulates, the earth is shielded from the falling rain by a thick protective cover, and soils develop a stable crumb-like structure. In the sub-tropics the same amount of rain may

fall in five months, the countryside drying out during the other seven months of the year. Grasses survive as isolated tussocks and thick masses of highly inflammable material, left from the previous year's growth, produce great fires which are a danger to human and animal life and even to aircraft. Yet when controlled, fire can be a useful tool to prevent the spread of poor bush and scrub trees.

Even under the best farming conditions it is difficult to maintain a thick mat of vegetation through the dry season, and by the beginning of the rains the soil has little protection from the pounding effect of rain drops.

To the divergence in the annual distribution of rainfall in England and Rhodesia is added an important difference in the intensity with which it falls. For example, the amount of rain which falls in about 450 hours in Plymouth (one of the heavier rainfall areas in England) will fall in Southern Rhodesia in about 250 hours. One must expect rainfall delivery in Rhodesia to be at least double that in a temperate climate, and often very much more. Two inches in an hour is a common intensity, four not uncommon, and the highest recorded rate is eight inches in sixteen minutes—about 1,100 tons of water pounding every acre in a quarter of an hour.

With the erosive power of running water proportional to the fourth power of its rate of flow, the devastating effect of these heavy storms, falling on unprotected soils, can be enormous. The farmer and the conservationist in Rhodesia must always bear in mind that, sooner or later, a farm will have to endure one of these storms and, even if it only occurs once in twenty years, more damage will be done in those few hours than in the remaining twenty years, unless the conservation works hold.

Standing at the crest of Central Africa, many rivers rise in the Rhodesias and flow to the Indian Ocean. In a few hours' walk around Salisbury a man can see the source of a score of streams. It is natural that each of these should slowly erode its headwaters in the timeless evolution of the continent and levelling down of the central plateau.

All these factors were at work before the country was opened up seventy years ago, but the introduction of civilisation, with increased populations of humans and stock, and the development of roads, railways, mines and more intensive agriculture has disturbed large areas of top soil and increased the vulnerability of the country to erosion.

Protection of Natural Resources

In the late nineteen-thirties it was realised that a serious menace to the future of the country existed. The benefits of simple conservation measures were clear on the farms of a few, but the destruction of fertile lands could be seen throughout the Colony. The late Justice McIlwaine, a man of great experience, was appointed to preside over a commission to consider the state of the Colony's natural resources. No man has done more to secure the prosperity of Rhodesia, and none had a wider and deeper appreciation of the problem. His memory is preserved most fittingly in the great Lake McIlwaine, on which the city of Salisbury relies for its water supplies.

The report produced by the commission greatly disturbed responsible opinion and resulted in the Natural

A falling rain drop.

The explosion which results from the impact of a rain drop on the soil surface.

The Umzururu river is normally 15 ft. wide at this point: after two hours of rain it is unrecognisable.

Conservation of water is essential to irrigation: here water is being pumped to tobacco seedbeds.

Resources Act. This Act set up a Natural Resources Board—independent, non-political and invested with responsibility for the natural wealth of the Colony. The Board, with a small permanent staff, works through intensive conservation area committees, which are formed as a result of petition by the local landowners. There are now over 90 of these committees in Southern Rhodesia, covering all European farming areas. In Northern Rhodesia a similar Act was passed about ten years later and 20 committees have been formed.

The committees hold a highly respected and responsible position in their communities; they are able to organise conservation works, borrow money and operate machinery for the construction of dams and conservation works; and they have, through the Board, adequate legal powers to safeguard their area, though these have rarely had to be used as the need for sound conservation is widely appreciated. Few farmers are unappreciative of the financial benefits to themselves of sound conservation and the certainty of the declining profits and of neighbourly criticism if they let their farms erode are usually adequate spurs to action.

The widespread support for the cause of conservation in Rhodesia is no accident. It has had to be earned laboriously, farm by farm—at first by the effort of a few who laboured by day laying out conservation works and by night carrying on administrative work and preparing literature. Weekly broadcast talks, an annual conservation week (when all schools are addressed), courses for teachers, and frequent articles in the Press, have accompanied the construction of over 5,000 dams, 44,000 miles of contour ridges, and innumerable road alignments, storm drains and water-ways, in the last ten years.

For some years conservation work was directed by the Department of Irrigation, but since 1948 a Department of Conservation and Extension, with a trained staff, has been built up. This Department now undertakes conservation duties and advises on all farming matters. Each intensive conservation area committee, responsible for 50-120 farms, likes to have its own conservation officer who will know all the farms and farmers, advise the committee and supervise the execution of conservation policy.

Good Conservation . . . Better Farming

At first, effort was naturally concentrated on the mechanical protection of land: contour ridges, storm drains, gulley reclamation and the construction of dams and weirs. Although there are now few European farms which have no such system of protection, this type of work is not likely to decrease as new land is continually being opened up and improved techniques are always being worked out. Nevertheless, it has always been realised that this is not enough. Farmers complain that despite improved seed and heavy applications of fertiliser their yields are not always better than many years ago when they had neither of these advantages. (This bears out experience in the U.S.A. where all the improvements in farming in the last fifty years have almost been offset by loss of fertility through soil erosion, and experience in Egypt, where improvements have been offset by the rising water table, due to bad methods of irrigation and inadequate drainage.)

This picture shows how tobacco ridges become eroded after heavy rainfall.

Building an earth wall spillway to a dam; it will later be faced with rocks.

To rebuild the fertility of the soil is the task now before us: this is something which can only be done by conservation farming—and fortunately conservation farming is profitable farming. Rotation of crops, heavy yielding crops, productive grass leys, systematic veld grazing—these are subjects of continual discussion in the farming Press and amongst leading farmers, whose initiative sets a forcing pace for the experimental stations which wish to prove new methods before they are widely adopted.

The Power of the Rain Drop

It has been demonstrated that erosion begins with the bomb-like action of the rain drop falling on unprotected soil. Falling in their millions, rain drops break down clods to granules and granules to the finest particles, starting them moving and driving some of them into the surface soil. At this early stage very serious damage has been done, for the particles beaten into the soil seal its pores. Rain cannot penetrate the soil easily and the water needed for plant growth runs off the land instead of being stored in the soil on which it falls. The soil is sealed from the air, and plants will have difficulty in breaking through the hard surface layer. The water, which should have been absorbed into the soil, now finds channels down which it flows, taking the particles thrown up by the rain drops and adding to them by its own scouring effect. This flow continues until it is checked, perhaps by a dam in which the burden of unwanted soil is deposited, in which case it decreases the storage capacity of the dam.

Experiments have shown an annual loss of soil varying from 60 to 250 tons per acre from bare land; as there are about 1,200 tons of top soil to the acre, which may take centuries to produce, the effect of such erosion on yields and land values is obviously drastic. With a dense grass cover—or if, for experimental purposes, the soil is protected by fine gauze—the force of the rain drops is broken and soil losses fall to figures varying from one-tenth of a ton to 2 tons per acre. Work using gauze protection has shown that the conservation value of grass lies very largely in this protection from the pounding of rain drops, and not in the holding effect of grass roots.

Little is known of the amounts of water needed by crops at various levels of yield, and investigation into this subject has begun. But it is believed that in many years the yields of crops in Rhodesia are depressed by low rainfall; if this is the case, then the loss by run-off must be avoided. On bare land, over 40 per cent. of the rainfall has been lost, whilst under good grass or a heavy yielding crop only 3-8 per cent. will be lost.

When applied to normal cropping these basic observations have aroused great interest. Experiments have shown that maize, regarded as a bad crop from the conservation point of view, can, under suitable conditions, be an excellent conservation crop when grown to yield 4 tons of grain and give a plant population of 15,000 to the acre. Even when grown on slopes, losses have been small under these conditions. These experiments have conclusively proved the value of heavy yielding early crops for good conservation—and early crops are also profitable crops.

To assist farmers in the safe development of their farms

These tobacco seedbeds are laid parallel to an irrigation stream; in this way erosion by rain is minimised.

A good crop of tobacco, grown as a result of careful conservation.

and in making the change from extensive to intensive farming, the Department of Conservation and Extension has for some years been studying methods of farm planning. A practical system has now been evolved and a specialist section set up for this purpose. During 1957 all members of the staff were trained in the necessary techniques involved and many other departments of the Southern Rhodesian and neighbouring Governments have sent their officers to take part in this training.

The object of farm planning is to produce, according to the farmer's own inclinations, and in conjunction with him, a definite and detailed plan for the development of the farm on a sound conservation and economic basis. The plan is essentially the farmer's own, and constitutes a personal target. The demand for this service has grown in one year to embarrassing proportions and is now given high priority by the Department. In addition to the farmer's wishes, the planning system is based on a thorough classification of his soils, carried out with the use of aerial photographs and soil pits. The soil classification is shown on a large scale photograph of the farm which enables identification of soil class boundaries to be carried out with ease. On a similar photograph is drawn the system of conservation works, cropping rotation to be employed, fence and road lines and dam and weir sites. House and farmyard plans can also be put on the photograph if needed. The two photographs are supported by a detailed written plan.

In time, each individual farm conservation system will fit into an overall plan for the whole river catchment in which the farm lies.

The valley of the Sabi River in the east of Southern Rhodesia contains valuable irrigation soils and mineral deposits. To develop these assets will require large water storage dams. But the erosion of soil in the valley—recently estimated at 50 million tons a year—would rapidly fill the dams with silt and reduce their useful life. By bringing the whole valley up to the highest standards of conservation farming its soils are being established and soil losses reduced to a level which will ensure that the dams will have an indefinite useful life.

Experience in other parts of the world shows many examples of dams silting up a few years after being built, and becoming useless, because clearance is expensive and largely impracticable. In 1957 the Southern Rhodesian Government sent a team of conservation officers into the valley to prepare a plan for the whole catchment. Earlier this year 87,000 acres had already been covered and eventually the whole valley will be planned for conservation farming, the soils established and the dams built in the certainty that they will continue to provide water and power indefinitely.

This approach, catchment by catchment, must be the aim of all countries having climates which make soil conservation a necessary safeguard for the standard of life of future generations. The people of Southern Rhodesia are well aware of the fate that has overtaken many older civilisations faced with similar erosion problems and are planning increased prosperity for the future by means of the principles that have been touched upon briefly in this article.

Books

SEASONAL MOVEMENT OF INSECTS

Insect Migration. C. B. Williams, Sc.D., F.R.S. New Naturalist Series, Collins, London. 30s.

For centuries man has recognised the existence of regular seasonal movements of birds, but apart from the attention drawn to passing swarms of locusts by their wake of devastation, only in more recent years have we become aware of migratory flights occurring in insects. Eighteen years ago Dr. C. B. Williams published his first book on such flights in butterflies: he has now written a long awaited successor, *Insect Migration*, on a more general basis.

In his new book Dr. Williams has appreciated the fact that few people are aware of migratory movements in insects and he introduces the subject by pointing out that, contrary to popular belief, many insect species have a sufficiently long adult life to permit migratory flights over appreciable distances. Furthermore, in tropical regions directional flights of insects have been incorporated in folk lore and superstitions, whilst it is generally known that some species appear at certain times of the year without being found at any stage of their development at other times. Dr. Williams therefore devotes the first half of his book to a consideration of the evidence of migration in Britain and other countries, principally of butterflies and moths, and also of other insects, including locusts, dragonflies and ladybirds. He reviews in general terms the distribution of a large number of species and the recorded observations of their abundance and movements, frequently presenting the data in the form of readily understandable diagrams.

Naturally a number of problems spring to mind. Do all migratory flights take the same form? Is migration simply a case of following the leader? How do the insects orientate and maintain a flight direction? Is there a return flight and a possible 'learning', as in birds? Dr. Williams sets out in his characteristically stimulating way to answer these and a number of other questions.

A migration may be considered in terms of its 'front' or width, the number of insects passing on this front per hour and the total time involved. For the interested reader, a scheme has been proposed on this basis for a simple estimation of the number of insects involved in a migration. Evidence of distances covered must generally be inferred, but the author leaves little doubt that flights of 2,000 miles or more can occur. He has long been known to hold the view that many species of both migratory and non-migratory insects fly equal distances in a day, but that the former fly in a more or less straight line.

Even if we can establish how an insect successfully navigates we are still left with the problem of why it should do so. It is generally considered that in nature if a feature is to persist it should convey some advantage to the insect. Certainly in locusts

the factors operating in swarm flights appear to be of ultimate value in that they carry the insect, partly through the action of winds, into areas of rainfall, necessary for both egg hatching and fresh plant growth. Migration, however, does not simply occur as the result of the development of overcrowded conditions, although these do contribute to swarm formation in locusts.

The problem of insect abundance has occupied the attention of entomologists for many years. As soon as the population density of any one species increases above a certain limit, that insect is likely to rank as a pest, gaining the attention of entomologist and economist alike. Dr. Williams discusses some of the factors involved in the fluctuations that commonly occur, including the drastic effects of insect immigration and the insect's relationship with its natural predators.

On reading this interesting survey of our knowledge of insect migration, one is made only too conscious of the need for more observers and more observations, and of the large number of problems still waiting to be answered. Why, for example, should a single species be migrating, at one and the same time, northwest in one part of the world and east in another? In the biological sense, what does migration mean?

The personal form of presentation in this book, with its anecdotal style, not only makes very good reading but is likely to excite the casual observer into a desire to assist in this most promising field of study. It is fitting, therefore, that Dr. Williams has devoted the last part of his book to a consideration of techniques and the collation of data.

There is a good reference list, arranged historically, and an adequate index which, with the systematic arrangement of the book, should make it of value to the technical reader. The book is virtually free of typographical errors, but it does not carry the number of plates one would like to see, though the eight colour plates are of a reasonably high standard and there are 16 plates in black and white. To some extent the author makes good this deficiency by his liberal use of clear original diagrams. —D. B. LONG.

COTTON PRODUCTION UP-TO-DATE

Cotton. H. B. BROWN and J. B. WARE. McGraw Hill. 93s. or $12.

The third edition of *Cotton*, which has recently been published, gives an up-to-date masterly account of the world's cotton production. This revised edition has been adequately illustrated with new and instructive material; it is presented in simple language which makes it both interesting and easily absorbed, yet it has been written with a thoroughness that renders it of infinite value as a text book for students in North America and as a useful book of reference there and elsewhere.

After giving an accurate but concise history of cotton and the cotton industry the authors take us out into the field, explain the taxonomy of the cotton plant in detail and later give us an account of current varieties, their merits and respective peculiarities. Here they cover a wide field but naturally deal with North American varieties in greatest detail.

The necessity for standardisation of cotton varieties is stressed and a detailed description of methods used in various parts of America and in other countries, for maintaining seed purity and for the multiplication and distribution of new and improved varieties, is given. The importance of a fool-proof system of seed control which makes for improvement, sanitation, and absolute purity, cannot be over-emphasised, because the success or failure of any cotton crop may well depend upon efficient methods of seed control, at the stores and warehouses, in ginning factories, distributing centres and in the field. In this book all these factors are taken care of and ways and means of applying controls are described.

Chapters 5, 6 and 7 should be of particular interest to cytologists and cotton breeders. These chapters deal with the fundamental structure of the cotton plants and describe in a fairly simple manner the structure of the adult plant, the reproductive structures, the seed, the forming of seedlings, the structures of the fruit, variation, heredity and correlation of characters in the cotton plant. The problems and modern methods of cotton breeding are described in detail.

The discussion on cotton diseases is well illustrated and gives a fairly comprehensive description of the diseases of this crop, together with their distribution, symptoms and control measures. However, that on insect pests indicates that the necessary limits of the space which can be given to the discussion in a book covering so wide a field reduces the description of individual insects for serious purposes to not much more than an introduction to the subject.

Under the heading 'Physiology of the Cotton Plant', the authors give reasons and explain the causes of seasonal yield variation due to factors other than pests and diseases, and tell us why seed remains viable in some climates for much longer than in others. They also present, in condensed and simplified form, the findings of plant physiologists and agronomists, and include defoliation studies for mechanical harvesting.

Much time and patience have been devoted to soil fertility and cotton culture, harvesting, etc., and a meticulous description of the latest cotton picking machines is given. The Sudan Gezira is, however, described as being highly mechanised for all operations except picking. Probably the reason why cotton has not been picked mechanically in the Sudan is because the varieties grown there are, being of Egyptian origin, long stapled, slow maturing varieties which do not open their bolls in one flush, as is the case with some American varieties, but have to be picked from five to six times during a season. A machine which will accomplish this without damaging the cotton plant and seriously lowering grade has yet to be designed.

A short history of cotton ginning is given and methods of seed cotton cleaning and processing before ginning are described. More time and space has been given to saw ginning than to roller ginning; this is understandable because, except for special quality long stapled cottons which form only a very small parcel of the world's production, roller ginning has become a thing of

the past. If, as it would appear, the authors are referring to naked seeded long stapled varieties, in their discussion on roller ginning, the lint output per hour (50-80 lb.) seems rather conservative.

Towards the end of the book the reader is given an introduction to cotton classing and marketing, and the intricacies of cotton future exchanges are explained. Finally, the manufacturing of cotton fabrics, the cotton seed processing and by-products are discussed.

As an up-to-date textbook for students and a reference book for all cotton workers, the book can be unreservedly recommended.—R. R. Anson.

DECADE OF WORLD FERTILISER PROGRESS

Annual Review of World Production and Consumption of Fertilisers, 1957. F.A.O., 1958, H.M.S.O., P.O. Box 569, London, S.E.1. 5s.

Both world production and consumption of fertilisers have continued to increase steadily: 1956 production rose by 5 per cent., consumption by 7 per cent.; for 1957, a further 4 per cent. increase for both is estimated. The forecasts for 1958 show a slightly smaller trend of increase but forecasts are necessarily conservative. So far as this latest FAO Report is concerned, however, the year-by-year changes are of less significance than the figures for 1946-47 to 1956-57. For the first time FAO has been able to survey a decade of world fertiliser progress.

Expressing fertiliser consumption as metric tons of N, P_2O_5, and K_2O (*in toto*), this comparison can be made:

	Plant foods, 1,000s tons
1946-47	8,850
1956-57	20,639

It should be borne in mind that these totals exclude consumption in USSR, China, North Korea, etc. There is little doubt that Russian and Chinese consumption has also greatly risen. World use of fertilisers in the first post-war decade has expanded, therefore, by at least 2.3 times, or by 130 per cent.

The distribution of expansion follows much the same pattern as the distribution of formerly well-developed use. If these world totals are split, as in the FAO Review, into two parts—use by 'highly-developed countries' and use by 'the rest'—the accompanying figures emerge:

Table I

	Plant foods, 1,000s tons 1946/47	1956/57	Ratio	Agricultural land Millions of hectares	%
Highly-developed countries ..	7,599	16,964	2.2	1,160	38
Rest	1,251	3,675	2.9	1,900	62
Total	8,850	20,639	2.3	3,059	100

That is, ten years ago 87 per cent. of the world's fertilisers was being applied to 38 per cent. of the world's agricultural land. After a 2.3 times expansion in ten years, 83 per cent. is still being applied to the favoured 38 per cent. It is likely to the point of certainty, of course, that if more of the expansion had occurred where fertilisers had been less used before, world food production would have risen much more. This, too, is almost wholly a picture of the so-called Western World (politically though not geographically); if it were a complete picture, would the expansion of consumption by less-developed and under-developed countries show a better figure? There is much food for thought in this question. Certainly, it could be argued that Western leadership and aid in development should have stimulated greater expansion outside those countries where fertilisers are accepted materials of farming.

Population pressure upon agricultural land is clearly a major factor in determining a country's rate of fertiliser use. The following table for 1956/57 fertiliser usage is given:

	Metric tons of fertiliser plant foods ($N+P_2O_5+K_2O$) per 1,000 hectares (1956-57)		Metric tons of fertiliser plant foods ($N+P_2O_5+K_2O$) per 1,000 hectares (1956-57)
Japan	215	Italy	36
Belgium ..	199	Switzerland ..	34
Netherlands ..	196	Portugal ..	26
Norway ..	140	Ireland ..	23
West Germany	135	New Zealand ..	19
Denmark ..	121	Spain	18
Luxembourg ..	101	Iceland ..	15
Finland ..	71	USA	13
Sweden ..	64	Canada ..	4
United Kingdom	52	South Africa ..	4
France ..	52	Australia ..	1
Austria ..	42		

The average rate of use for Western Europe is 55 tons of plant food per 1,000 hectares.

It is only necessary to pick out the relatively low rates of use for New Zealand, Canada, and Australia to appreciate that where the land resources are large compared with population, over-all fertiliser use is still small. However, the over-all average per 1,000 hectares is misleading unless it is realised that it implies a very low usage on large areas of farmland side by side with a normally full usage on smaller areas of farmland, which are no less intensively cropped than farmland in Western Europe.

Expansion of fertiliser use in large countries seems completely dependent upon the factor of population pressure. Countries whose land resources are high but whose populations remain low are unlikely to show striking increases in the future—additional output of food would first require certainty of additional market for it. Mexico and South Africa are cited as examples—they have respectively 2.9 and 7.1 hectares of farmland per head of population. The case of India stands in sharp contrast—there only 0.4 hectares of farmland exists per head of population. This difference is characteristic of Asia (excluding the Near

East), and in the post-war decade fertiliser use has shown steady increase, as shown in Table II.

Table II

	1947	1952	1953	1954	1955	1956	1957
S. and S.E. Asia	75	181	245	251	280	327	183
India	44	69	129	104	143	161	182

(Total consumptions as 1,000s of metric tons, $N+P_2O_5+K_2O$)

Turning from the world picture, some interesting information given in the *Review* for types of fertiliser now used in Western Europe should be mentioned. The relative proportions of 'types' for 1956 and 1957 are given as follows:

Nitrogen

Ammonium nitrate	40	per cent.
Ammonium sulphate	26	,,
Calcium nitrate	12	,,
Calcium cyanamide	6	,,
Sodium nitrate	3	,,
Others	0.4	,,
Complex fertilisers	12	,,

The only recent change shown is for N in complex fertilisers, which has risen from 8 to 12 per cent. since the previous FAO *Review*.

Phosphate

Single superphosphate	55	per cent.
'Double' superphosphate ..	5	,,
Basic slag	19	,,
Ground rock phosphate ..	6	,,
Others	4	,,
Complex fertilisers	10	,,

Recent changes are a sharp fall in the proportion of basic slag used, and rises in superphosphate and complex fertiliser proportions.

Potash

Potassium chloride, over 45% K_2O	48	per cent.
Potassium chloride, 20-45% K_2O	35	,,
Crude potash salts, 20% K_2O or less	4	,,
Potassium sulphate	4	,,
Others	2	,,
Complex fertilisers	7	,,

European countries showing marked preference for using the lower grades of potassium chloride fertilisers are Austria, Belgium, Western Germany, Italy, the Netherlands, Norway, Switzerland, and Yugoslavia.

The changing picture of $N : P_2O_5 : K_2O$ ratio in Western Europe's use is shown in the *Review* by Table III.

Table III

	N	P_2O_5	K_2O
1936-38	1	1.58	1.36
1949	1	1.41	1.28
1953	1	1.26	1.36
1954	1	1.25	1.31
1955	1	1.18	1.24
1956	1	1.16	1.18
1957	1	1.14	1.16

To many the decline in *relative* use of potash will be more surprising than that for phosphate.—D.P.H.

(*The above review is reprinted from the* Fertiliser and Feeding Stuffs Journal, **XLVIII,** 9, *by permission of the Editor.*)

Methods of Weed Control. Earl A. Helgeson. FAO Agricultural Studies No. 36, Food & Agricultural Organization of the United Nations, Rome. 10s. or $2.

While in this booklet it is recommended that control of weeds should, where possible, be by cultural methods, which are fully described, it is the wide and explicit coverage given to chemical weed control which proves to be the most interesting reading. It is a pity, though, that no mention is made of the phenoxybutyric weedkillers, or of simazin, but there was probably insufficient information available on these products when the work was compiled.

The booklet covers many aspects of weed control, with separate chapters devoted to equipment, control of aquatic and woody weeds, and weed control in field and horticultural crops. Although it is not possible in such a general publication to cover all the techniques used for the control of weeds in every crop, the most popular and widely used methods are discussed.

A separate chapter is included on the control of 41 important weed species. This is a particularly useful chapter, though it is somewhat surprising to find that the section on lallang (*Imperata cylindrica*) makes no mention of the successful use of straight oil herbicides for the control of this plant.

Appendices contain a comprehensive list of over 800 plant species, showing their susceptibility to treatment with the more common herbicides, a brief list of the chemical names of herbicides, a glossary, and weights and measures conversion factors.

This is a useful and authoritative booklet which will prove of interest to those concerned with the problems of weed control. —I.A.H.S.

Flora of the British Isles. A. R. Clapham, T. G. Tutin and E. F. Warburg. **Illustrations,** Part 1: *Pteridophyta—Papilionaceae*. Drawings by Sybil J. Roles. Cambridge University Press. 25s.

The illustrations of the species are given in the same order as is followed in the companion text, *Flora of the British Isles*, by the same authors. The *Illustrations*, by Miss Sybil J. Roles, were drawn from fresh specimens and are intended to convey the appearance of the living plants; unfortunately, though, this has sometimes resulted in poor detail and sketchy diagrams.

The *Illustrations* are more comprehensive than those given by Fitch and Smith (*Illustrations of the British Flora*) and are better in that they are larger and each is drawn to scale. They may well prove useful to experimentalists concerned with the easy identification of plants susceptible or otherwise to weed killer applications, but they suffer from the disadvantage that details of floral structure are not always clear. A short explanatory note below each illustration would have immeasurably improved the usefulness of this volume. As it stands, it has to be used in close conjunction with the companion text. —E.W.B-J.

IN THE MARSHES OF SOUTH IRAQ

by **A. B. Harris,** *The Shell Petroleum Company, Ltd.*

A supervisor and team prepare their equipment before carrying out anti-malarial spraying in a south Iraq island village.

A four-wheel drive lorry, supplied to the Iraq Health Service by UNICEF, moves on over the rough desert track, leaving behind it a long curling cloud of light fawn dust. It is travelling towards the marsh region of southern Iraq, part of the alluvial plain that is dominated by the two great rivers, Tigris and Euphrates.

This country, though greater in size than the Low Countries of Europe, is rarely visited and is little known to the outside world. It is inhabited by an ancient tribe known as the 'Ma'dan' or marsh Arabs, a people who live in small villages on the many islands formed in the marshes, their numbers varying according to the size of each island.

The Ma'dan dwellings are built entirely of reeds, plaited together to make matting which is draped over a ridge pole to form a hut similar in shape to a Nissen hut; smaller mats at each end complete the structure, which is on average 12 ft. long and approximately 5 ft. 6 in. high. The low doorway—usually only 3 ft. high—and any gaps there may be between the reed mats, provide the only light and ventilation.

Spraying the interior surfaces of a summer hut, built entirely of reeds.

The Ma'dan have little contact with the outside world as their only form of transport is a kind of wooden canoe, known as a *machouf*. These people and their animals live side-by-side and frequently share the same sleeping quarters. All available land is utilised to provide food for the inhabitants, who are self-supporting, and it is not uncommon to see goats, sheep and water-buffalo emerge from the reed huts to graze an area which appears to be devoid of nourishment. The water-buffalo is kept not for meat but for its milk and dung, the latter being used as fuel.

Despite their skill at eking an existence from this waste land of marshes, the standard of life of the Ma'dan is very low, and they fall victim to many diseases. The chief scourge amongst these is malaria.

It is to rid the marsh Arabs of this dreaded disease that insecticides have been used this year as part of a programme of malaria eradication foı which Iraq has received economic aid from UNICEF and technical advice from WHO.

Water buffaloes taking to the water at the edge of an island village.

WORLD HEALTH ASSEMBLY DISCUSS MALARIA ERADICATION

One of the most important subjects discussed at the eleventh World Health Assembly, held at Minneapolis, USA, last June, was malaria eradication. The Assembly, which met for three weeks under the chairmanship of Dr. Leroy E. Burney, Surgeon-General of the US Public Health Service, was attended by delegates of all the 35 active member states of the World Health Organisation, as well as by representatives of the United Nations and other bodies.

In discussing the malaria eradication programme, as it is evolving throughout the world, many delegates reported a significant extension of the work, and it was shown that eradication is now under way in 76 countries, embracing nearly one-third of the world's population. It was stressed, however, that greater international financing was going to be essential if malaria was to be eradicated from the entire world within a relatively short period. So far, a little over \$5m. had been contributed to WHO for malaria eradication—a sum only sufficient to complete the 1958 programme. Tribute was paid to UNICEF for having made substantial contributions.

In the field of research, WHO was asked to promote further work on malaria, particularly in connection with the development of insect resistance to insecticides. The Director-General was also asked to organise and arrange for a special study of the rôle of WHO in research, and of ways in which the Organization could give more adequate help in stimulating and co-ordinating research and developing research personnel. For this purpose the US Government is making available some \$3m. to WHO to set up studies for ways and means by which research can best be promoted.

The Organization is to investigate concrete measures for dealing with the health aspects of atomic energy, and will report especially on methods of ascertaining and recording the radiation exposure of individuals from all sources. Of equal importance will be reports on methods for determining the relationship between radiation dosage and congenital defects, and for notifying the public health authorities of congenital defects which might be due to radiation.

The First Ten Years of WHO, a comprehensive report which reviews the work of the Organization since its inception in 1948, was presented to the Assembly. A new WHO survey of the world health situation is to be made available; it will cover the period 1954-1956, and will contain descriptions and appraisals of health programmes completed or in progress in 157 countries and territories.

The next (twelfth) World Health Assembly will meet in 1959 at the WHO headquarters in Geneva.

NEW LOCUST INFORMATION SERVICE

In recent months large-scale breeding of locusts and grasshoppers has been taking place in various parts of the world; this has been due to especially favourable weather conditions. The desert locust in particular has been very active, and reliable reports indicate that an even more serious situation than exists at present is likely to develop during the next twelve months.

The control of the desert locust is one of the most pressing of all current pest control problems. Recent FAO estimates put the cost of control at approximately US \$30m. per annum. During the nine years, 1949-57 recorded losses resulting from crop damage amounted to approximately \$42m., but this figure does not fully represent the effect of the desert locust on the economy of the countries involved; it does not include the losses incurred as a result of widespread devastation of food crops, nor does it show to what extent the desert locust is a potential danger to all agricultural crops grown within the area.

The total distribution area of the desert locust amounts to approximately one-eighth of the world's land surface and includes some 50 different countries. The organisations required to control the pest are administered at government and international level, great emphasis being placed on the importance of international co-operation.

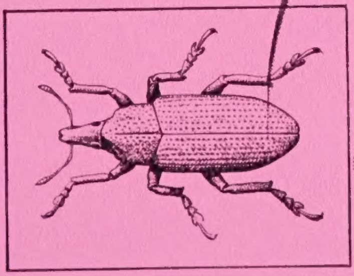
Particular stress was laid recently at the fifth session of the FAO Desert Locust Control Committee on the need for accurate and regular reports of the sighting of adult swarms and of hopper bands. To deal with these reports, an organisation—the International Desert Locust Information Service (IDLIS)—has been set up. This service is sponsored by FAO and operated by the Anti-Locust Research Centre in London. All swarm reports received are sent to IDLIS and from them is prepared a monthly situation summary in which the prevailing situation is reported, and a forecast made of likely future developments. The service, which is a continuation of one previously given entirely by the Anti-Locust Research Centre, will prove of great value to all who are concerned in the preparation of plans to combat the desert locust menace.—H.A.L.

Time of the Weevil

When spring returns to Lombardy and the reed-fringed canals, which thread the plain like veins in an outstretched hand, once more reflect a limpid sky; when warm sunshine mellows again the pink-washed walls and the sensual winds of the south push winter more firmly into the ice-galleries of the Alps, then farmers watch their fields with an anxious eye. For to *bieticultori* spring is the time of the weevil, and in a few days an entire planting of sugar-beet can be devastated by a pest which attacks both above and below ground.

The sugar-beet weevil, *Temnorrhinus mendicus* Gyll., known in all the warmer countries of Europe, is regarded in Italy as a pest of major importance. Infesting the fields in spring, the adult insects feed busily on the young beet leaves: eggs are laid and the grubs hatch out within a few days, to begin feeding greedily on the roots. This double attack, which can reduce the yield by as much as 85%, is a serious matter both for the individual farmer and for the great 12 year scheme for the Development of Italian Agriculture now in progress, under which a constant effort is being made to raise the production level on all Italian farms.

Because of this, the authorities ran a special campaign in 1956 to control the weevil. In an ambitious scheme throughout the sugar-beet areas, aldrin, the Shell soil insecticide, was widely used as one of the chief weapons of destruction — both because of its effectiveness *and because of its economy*. Applied at a rate of 2lb. per acre, aldrin was sprayed and dusted over the growing crops and achieved complete control, not only of the weevil itself but of other destructive insects. Aldrin, indeed, represents *morte fulminea*, sudden death, to most pests of the soil.



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